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The Authority on the Future of Technology
August 2011
www.technologyreview.com

technology
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technology review

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De Technologia non multum scimus. Scimus autem, quid nobis placeat.

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Letters and Comments

THE DEMAND FOR RARE EARTHS

The May/June 2011 story "The Rare-Earth Crisis" unfortunately opens with a common fallacy: "Today's electric cars and wind turbines rely on a few elements that are mined almost entirely in China. *Demand for these materials may soon exceed supply*" (emphasis added). Demand and supply are connected by prices, and if supply changes, prices change and generate a new equilibrium. At no point does demand "exceed" supply. When prices rise, substitutes or new sources of supply—or new technologies—emerge. This is especially true of rare earths, because they aren't really "rare"—just costly and environmentally dirty to produce. The real advantage the Chinese have had is that they have been willing to tolerate pollution from rare-earth mining, something they might be increasingly unwilling to do. Yes, the Chinese can create and exploit short-term disruption, but in the longer term, they will only encourage greater production or substitution elsewhere.

Louis S. Thompson
Saratoga, California

Materials shortages are not a new phenomenon, but the rare-earth crisis described by Katherine Bourzac portends a change in their nature. In the 1970s, the best permanent magnets were made of an alloy of samarium and cobalt, with the cobalt coming almost entirely from mines in Zaire. When Zaire became politically unstable, cobalt supplies dwindled and prices rose, spurring the research that produced the neodymium-iron-boron magnets that we use in today's high-tech motors and generators. Neodymium-iron-boron outperforms samarium-cobalt in most respects, so this shortage had a positive outcome for magnet technology. We can only wish for such outcomes today. Technologies have grown more complex, and devices today can use 50 or 60 elements, rather than a handful. The rare earths are notable for the specificity of their properties, the interconnectedness of their sources, the rapid growth of industries that depend on them, and China's near monopoly on their supply. They are essential components of best-in-class magnets, phosphors, lasers, fiber optics, catalysts, abrasives, and more. Never before has technology been so vulnerable to critical shortages. We need to predict supply crises better than we do today, and ensure that we have the ability to develop alternatives whenever shortages occur.

Alex King
Director, Ames Laboratory
Ames, Iowa

THE BENEFITS OF SNOOPING

As biomedical researchers, we read with interest the story on privacy by Simson L. Garfinkel ("How to Stop the Snoopers," March/April 2011). The article implied that data mining is a phenomenon promulgated by predatory corporations and designed primarily to encroach on people's personal lives and privacy. Among other things, data mining provides substantial benefits in genomic research by helping to sift through millions of data points to find actionable correlations between genes and diseases. Data mining is overall a socially valuable endeavor. The difficult part is finding a way to employ large-scale aggregate uses of data mining while protecting the privacy of the individual.

Dov Greenbaum and Mark Gerstein
New Haven, Connecticut

FUTURE SPACE TRAVEL

It's a joy to read about Space Exploration Technologies (SpaceX), a private company that collaborates with NASA in an effort to carry humans to space ("Rocket Road," May/June 2011). Private companies can do a great deal, but much more than NASA's occasional help is needed to pursue the old dream of space colonization. The infrastructure for such an endeavor would require international coöperation and resources from all space nations. Otherwise, we will remain glued to Earth. Or am I daydreaming well past the point at which space colonization has turned into a pipe dream?

Ranko Bon
Motovun, Croatia

WATSON'S INTELLIGENCE

Jaron Lanier states that IBM's "alchemical agenda" presented science in a "sloppy" way by pitting Watson, complete with its pleasant voice and canned banter, against human masters on *Jeopardy!* ("It's Not a Game," May/June 2011). Despite their justifiable pride, members of the Watson team have been uniformly sober and realistic. *Jeopardy!* is a fine way for a team working on deep question-answering systems to display their progress, draw the public into a teachable moment, and give it a glimpse of the scientific challenges involved and of experiences the future might hold with automated online help

May/June 2011

desks and other technologies. Lanier is in a long line of critics who keep moving back the goalposts: every time a minor milestone is reached, they claim, "But that isn't real AI." There's nothing mystical about Watson—just good problem identification, good science, good execution, and good presentation.

David G. Stork
Portola Valley, California

I was expecting the author to do a comparison between Watson's use of the discredited, 20th-century symbolic approach to AI and more promising, current AI research. Instead, I read a whiny essay about how IBM's *Jeopardy!* stunt is attracting enemies of science who are skeptical of evolution and climate change. This is truly lame. The public has the right and duty to be skeptical of science.

Louis Savain
Los Angeles

LEAKING SECRETS

I found your editorial and review on WikiLeaks ("Is WikiLeaks a Good Thing?" and "Transparency and Secrets," March/April 2011) thought-provoking. I think of a saying in psychology: You're only as sick as your secrets. The words "privacy" and "secrecy" are often used interchangeably, but they are actually distinct concepts. Privacy is a matter of mutual respect, while secrecy is more conspiratorial: keeping something hidden in the anticipation that others will try to discover it. The very proliferation of leaks means there are far too many secrets being kept. In a free society, official secrets should be at an absolute minimum. How can people make informed choices when information is being hidden from them? I'm glad that WikiLeaks exists, and I hope it's a Hydra that never runs out of heads.

Paul Vitols
North Vancouver, British Columbia

Fragile Steps

The dreams of millions ride on trials for a treatment that could allow the paralyzed to walk, says Roman Reed.

On March 1, 2002, Hans Keirstead handed me the future of medicine. It was a white laboratory rat, and holding it made me feel an odd mixture of awe, jealousy, and pure joy. It had once been paralyzed, like me. But the rat walked again.

That rat had been given a product derived from human embryonic stem cells—a product that I had played my own role in creating. A California law, the Roman Reed Spinal Cord Injury Act of 1999, had provided Keirstead's initial seed funding. Perhaps never has $92,000 been so wisely spent! The pharmaceutical company Geron acquired the rights to the process and fought its way past many obstacles and hurdles before gaining U.S. Food and Drug Administration approval for human trials *(see "Stem-Cell Gamble," p. 52)*. On May 4, 2011, the California Institute for

Regenerative Medicine lent Geron $25 million to help with the costs.

These important and required safety tests are hugely expensive. But this first-of-a-kind treatment could transform the lives of many people. Paralysis resulting from spinal-cord injury is a devastating condition that currently affects just under 1.3 million Americans. When the various other forms of paralysis are taken into account, 5.6 million Americans have a stake in the outcome.

The Geron trials will not immediately help folks who, like me, have been paralyzed for a while. These first trials are studying the newly injured. But when it comes to paralysis, what helps anyone helps everyone. These trials are creating and codifying a process that can now be used to test other treatments derived from embryonic stem cells—treatments for diabetes, blindness, and more.

These trials could show that we can actually cure the most disabling conditions instead of just maintaining people, often in misery. There are gains for the rest of society, too. Chronic illnesses account for 84 percent of total U.S. health spending, according to the Robert Wood Johnson Foundation. Regenerative medicine like that pioneered in the current trial offers the possibility of cutting those costs and bringing huge gains to the biomedical industry and the whole economy.

Unfortunately, the funding that made this research possible is now endangered. The future of the California Institute for Regenerative Medicine is threatened by the state's ongoing budget crisis. Meanwhile, funding for the Roman Reed Act recently expired, and I am currently campaigning to renew it. The Geron trial is a great start for this field, but we can't let future research with similar potential die on the vine for lack of support.

ROMAN REED WAS PARALYZED IN A COLLEGE FOOTBALL ACCIDENT AND IS PRESIDENT OF THE NONPROFIT ROMAN REED FOUNDATION, WHICH CAMPAIGNS TO SUPPORT DEVELOPMENT OF TREATMENTS FOR SPINAL-CORD PARALYSIS.

Nuclear Lessons

The Chernobyl and Fukushima nuclear accidents were failures of culture as well as technology, says Najmedin Meshkati.

I first saw the Chernobyl "sarcophagus" while driving in the exclusion zone on a bright spring day in May 1997. The shattered plant was an eerie, captivating presence *(see "Nuclear Cleanup," p. 30)*, and it was chilling to spend a few days in the control room of reactor 3 (which was then still operating)—an exact double of the exploded reactor 4. The fallout from that 1986 tragedy spread so far from the plant as to inspire the conclusion that a nuclear accident anywhere is a nuclear accident everywhere. No other industrial site has spread such devastation to the environment and the lives of so many millions of people.

Many credible studies have concluded that Chernobyl's disaster was caused by the safety culture in the Soviet nuclear industry at the time of the accident. A plant that fosters positive attitudes and practices with respect to safety encourages employees to ask questions and to apply a rigorous and prudent approach to all aspects of their job. It promotes open communication between line workers and middle and upper management. The Soviet safety culture was deficient in these respects, allowing dangerous risks to be taken.

My 25 years of research on nuclear safety in the United States, Japan, and elsewhere lead me to believe that a similar cultural failing lies behind the Fukushima Daiichi nuclear crisis. Of course, in the disaster's wake, we should be concerned with the risks that major earthquakes and tsunamis pose to nuclear power plants anywhere. Yet it seems that in this case, the natural hazards acted as a trigger for the ensuing
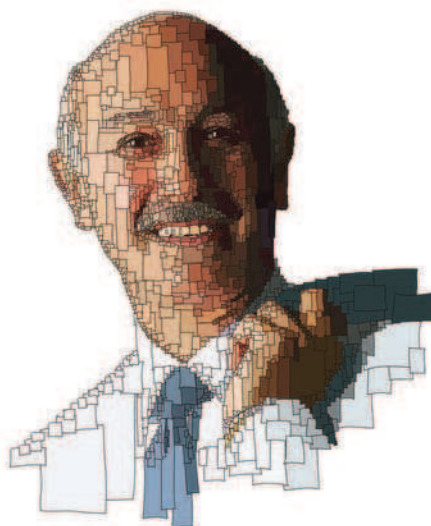
man-made disaster, which still affects many hundreds of thousands of people today. The root causes are lax or nonexistent regulatory oversight in Japan and an ineffective safety culture at the plant's operator, Tokyo Electric Power Company (TEPCO).

Japan's nuclear regulator has never been independent from the industry or from the powerful Ministry of Economy, Trade, and Industry, which promotes nuclear power. TEPCO has a history of disregard for safety and had recently released an error-prone assessment of tsunami hazards at Fukushima that significantly underestimated the risks.

For the foreseeable future, despite increasing levels of computerization and automation, human operators will remain in charge of day-to-day control, monitoring, and maintenance at nuclear plants. We should learn from Chernobyl and Fukushima that this global industry must strive for higher universal safety standards and closer coöperation among its members and regulators. The safety of these plants transcends national borders and has never been more important in the eyes of the public than it is today. We can do better than Chernobyl or Fukushima.

NAJMEDIN MESHKATI IS AN ENGINEERING PROFESSOR AT THE UNIVERSITY OF SOUTHERN CALIFORNIA AND HAS INSPECTED NUCLEAR PLANTS AROUND THE WORLD IN THE COURSE OF RESEARCH INTO THE INDUSTRY'S SAFETY.

HEALTH
Measured Progress

Apps to track the health of individuals are most powerful when we use them collectively, says Rachel Maguire.

A new breed of smart, connected tools and apps is enabling a band of early adopters to track and analyze their personal health data. This type of intimate relationship with health information has the potential to transform our perceptions of disease and risk. It can help people take earlier and more effective steps to address developing health problems (see "The Measured Life," p. 38).

Yet unless we carefully consider how to introduce these new applications to a broader population, a significant opportunity will be lost. The "quantified self" movement risks oversupplying enthusiasts with new gadgets while failing to reach those who would benefit most. Many people with much to gain are not served by this trend today, whether the barrier is limited financial resources, low digital literacy, or just plain lack of interest. We must find ways to reach them.

Simply giving those people access to the techniques pioneered by early adopters won't be enough: usually, the biggest barrier to good health is not a lack of detailed personal information about what healthy habits are and how well an individual is maintaining them. More often, people know what they need to do but are prevented by a lack of necessities such as nourishing food, clean air and water, a sense of physical security, and a supportive social environment. To help the many people in that position, health-tracking technology must deliver more than just extra, richer information.

How do we help the self-quantification movement reach this broader population? Perhaps by revisiting the unit of analysis.

Instead of equipping every person with tracking devices, we should devise ways to track, measure, and meaningfully present the findings at the community level. By quantifying communities, not just individuals, we can unleash the power of data to propel change.

Imagine the impact of being able to see extremely precise, real-time measurements of the air pollution that affects hundreds of children as they wait for school buses. Informing one child's parents about poor air quality at the bus stop may do nothing more than frustrate. Informing hundreds of par-

ents and activists that many embedded sensors found consistently high pollution may inspire action that leads to change. That's the vision of a project called CitiSense, an early foray into this type of participatory environmental monitoring and tracking. Another, Asthmapolis, pinpoints environmental triggers by tracking every puff of its participants' inhalers to reveal when and where asthma patients use their drugs. Both ventures are showcasing the most transformative power of these new data-gathering technologies: to provide diverse communities with information that can improve the long-term health and well-being of their members as a group.

RACHEL MAGUIRE DIRECTS RESEARCH ON THE IMPACT OF FUTURE HEALTH TECHNOLOGIES AT THE THINK TANK INSTITUTE FOR THE FUTURE.

The Problem with Waiting for Catastrophes

Human systems are not infinitely adaptable.

A few months ago, in a conversation about cybersecurity I was moderating at MIT's CIO Symposium, Erik Brynjolfsson, the director of MIT's Center for Digital Business, listed the complicated and controversial things that he felt would be necessary to make the Internet secure. He concluded by saying we might need to build a second, secure Internet, because the existing public network was not designed to be our global network for communications and commerce.

This sort of talk is not unusual. Beginning on page 46 of this issue, David Talbot describes a "perfect scam" in which Web users are shown bogus warnings that announce *"Your Computer Is Infected!"* and are then urged to buy fake antivirus software that provides no protection and sometimes conscripts the user's computer into a botnet controlled by malefactors. It's a billion-dollar criminal industry, and it's aided by the insecurity of basic parts of the overall networking infrastructure. Talbot has argued for years that we might need a new architecture that apportions security roles to various elements in the system *(see "The Internet Is Broken," December 2005/January 2006).*

Alas, discussions of new architectures inevitably run up against their prohibitive costs. What could inspire civilization to pay the price? At the CIO Symposium, Brynjolfsson had an idea: "Unfortunately, none of this is going to happen until there is a major disaster."

I was taken aback. I asked, *"What?* Are you saying that the public network will be grossly insecure until a digital catastrophe forces companies and governments to invest in new technologies and to agree to new mandates?" Brynjolfsson, still cheerful, answered, "Well, that would be consistent with human nature."

I should not have been shocked. Many economists consider it respectable to wait until a catastrophe strikes. Until something goes wrong, you don't know the scale of a problem: any preëmptive action will tend to allocate resources inefficiently. In addition, a precautionary response necessarily involves application of some variety of the precautionary principle—about which I wrote at this time last year, on the occasion of the explosion of the Deepwater Horizon drilling rig in the Gulf of Mexico *(see "On Risk," July/August 2010).* The precautionary principle states that when something new is suspected of being harmful, the burden of proof that it is *not* harmful rests with its proponents, and economists have always been suspicious of it.

In its weak formulation (which calls for users of new things to be prepared), it is unhelpful. In its stronger form (which calls for regulation or abstention), it has been a recipe for inaction. As I wrote, "No one knows how new technologies will be used in the future. There is *never* any consensus about risks. Crises accompany the development of any new, complex system, but their exact form tends to take us by surprise."

The blithe acceptance of catastrophes as spurs to action makes a sort of economic sense, although it can seem cold and unfeeling when we read, for instance, of historical instances such as Victorian administrators responding after the fact to Bengali famines. But the real problem with what can be called "ameliorative catastrophism" is that it assumes that human beings are infinitely adaptable.

In fact, the archeological record is replete with stories of societies that have not adapted to crises. In *Collapse: How Societies Choose to Fail or Succeed* (2005), the UCLA geographer Jared Diamond describes how a series of societies, from the Viking settlements in Greenland to the population of Easter Island, collapsed because their environmental strategies, appropriate at one time and place, were maladapted when circumstances changed. (I wrote about *Collapse* in April 2005 in "Let's Go Dutch.")

On page 26, David Rotman, *Technology Review's* editor, interviews Nicholas Stern, a former World Bank chief economist and the author of the 2006 Stern Review. No ameliorative catastrophist, Stern argued in his 700-page analysis that the costs of climate change, if not addressed, will be the equivalent of losing 5 to 20 percent of the global gross domestic product "each year, now and forever." Climate change, Stern wrote, "is the greatest market failure the world has ever seen" and could threaten hundreds of millions of people with hunger, water shortages, and poverty. Preventing such disasters, according to the report, would require investments equivalent to 1 percent of global GDP over each of the next 10 to 20 years.

In his interview, Rotman asks Stern whether the risks of climate change are so great that we must respond now even if we don't know how best to allocate resources. Stern's response? "You can't afford not to make those investments: the risks are too great, and the rewards are high if you do."

But write and tell me what you think at jason.pontin@technologyreview.com. —*Jason Pontin*

MARK OSTOW

TWENTY-FIRST CENTURY PREP:

SPANISH MACHINERY FOR FOOD PRODUCTION

Olive oil, chorizo, sherry, fine cheeses, and traditional tapas have earned Spain a worldwide reputation for gustatory delights. Spanish companies have also achieved international recognition for the quality of their agriculture machinery, food processing, and packaging, which is sold to customers in hundreds of countries that represent nearly every major market around the world.

In southern Spain, the sun shines nearly all year long, providing energy for its wealth of crops, which have made the region a breadbasket not just for Spain, but for much of the rest of Europe. In 2010, Spain exported more than 9.4 million tons of fruits and vegetables.

Food and wine have long been a source of national pride here, and a major attraction for the more than 70 million tourists who visit every year. "Then those tourists go home, and they want to continue consuming the olive oil, the wine, the oranges that they ate in Spain," observes Jaime Hernani, general director of AGEX, the Spanish association for food production machinery.

This has stimulated a boom in the export of not only Spanish products, but Spanish know-how in irrigation, cultivation, and cleaning, separating, processing, and packaging those agricultural products. Spanish companies that manufacture machinery for food production, he adds, have been selling their advanced technology throughout Europe, North America, and Asia for more than two decades.

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FAST, SAFE FOOD PROCESSING

Cured meat has been around at least since the time of the Romans, who ground fresh meat, salted it, and infused it with spices; fermented it to fuse the mass together; then allowed the meat to hang and dry for two to three months. The final products, such as salami, chorizo, and dry-cured sausage, are still popular today.

Josep Lagares, CEO of Girona's Metalquimia, working with Institute of Agricultural Research and Technology (IRTA) general manager Josep Maria Montfort, believed it was time for a change. Instead of a drying period that stretches out over several months, "We have reinvented this process to be able to dry these products in 20 to 50 minutes," says Lagares.

Metalquimia's innovation was to slice the meat before curing it, then send it through a machine that tweaks the humidity and temperature of the air inside to create the perfect curing conditions. The result: identical slices of cured meat. Its first industrial-scale machine, which can process 800 pounds of meat per hour, has been installed on the premises of the company's local partner, Casa de Mon.

Lagares sees endless opportunities for this machine. "For instance, [typically] if you want to try a new product in dry cured meat, you have to wait for months to see the results. With Metalquimia's [machine], you have the results in one day," he explains, adding that this technology will allow users to cure salt-free meat products, impossible with traditional techniques. And that's not the only benefit: Lagares points out that the space needed for meat drying can be reduced significantly, while a company can avoid having excess stock drying for months. This cure uses about 30 percent less energy than what many environments require to maintain the ideal temperature and humidity for long-term curing.

A focus on storage inspired Burgos-based NC Hyperbaric, whose technology improves the shelf life of minimally processed foods. In fact, according to marketing director Francisco Purroy, the company's continued dramatic growth can be attributed to two international movements. "There's a consumer trend towards foods and products that can be labeled as natural, minimally processed with no preservatives," points out Purroy. "At the same time, there's concern about [food-borne pathogens such as] listeria and salmonella."

NC Hyperbaric makes machinery that can kill pathogens in food without high temperatures, relying instead on extraordinarily high

levels of water pressure to shatter bacteria's normal functions and kill them. The company was one of the first in the world to bring this technology to an industrial scale for the food industry. In an NC Hyperbaric machine, packages of food are placed in a plastic chamber inside a steel vat. Water fills the vat beyond the volume of what a chamber of that size is able to hold. This increases the pressure just as if the package had been dropped deep into the ocean. While the high pressure kills microorganisms, the process leaves nutrients and taste alone.

This process allows minimally processed foods to enjoy a stable shelf life with less salt and no additives, says Purroy. NC Hyperbaric's newest and largest machine can process more than two tons of food per hour.

This technique has attracted the attention of drug manufacturers as well. Purroy explains that NC Hyperbaric has now partnered with an American company to use high pressure to unfold a protein, a better method for creating a drug used to treat multiple sclerosis.

NC Hyperbaric's research department is now focused on developing technologies that combine pasteurization and sterilization, melding high pressure and heat. "With heat, you need to heat the product to 120 °C all the way to the middle, keep it there for a time, cool it down," says Purroy. "This is all quite damaging to the quality of the product."

The temperatures used for sterilization with high pressure, however, will be significantly lower—80 °C—and applied for shorter periods of time, so the final product will retain a quality closer to the original than canned goods offer. NC Hyperbaric has a prototype in development and is continuing to investigate improvements to decrease the cost.

Heat is used not only to sterilize food, but also to sanitize the equipment to process it. Engineers at the hygiene machinery company Mimasa realized that the current requirements for washing and sanitizing—subjecting equipment to water that has been heated to 83 °C (181 °F) for three minutes—can take up to an hour to achieve. They reasoned that bacteria start to die off at lower temperatures, so the water could pass through these temperatures as the heat rises.

So they worked with researchers at Catalonia-based IRTA to determine the optimal temperature increase and the time needed at each temperature to kill the required number of a given microorganism. The resulting machine saves time.

SEEDS OF CHANGE

The greenhouse next to Conic System's seed-planting company in Barcelona is filled with the welcoming scent of new growth. The building houses budding plants that the company sells to hobby gardeners and growers. And the space also provides the perfect test bed for innovations in Conic System's seed-planting and irrigation machinery.

After decades in agriculture, the Gusi family still could not find a suitable machine to rapidly and effectively plant seeds

Companies are automating food processing and packaging machinery to speed processes and help eliminate human error.

Photo Courtesy of Metalquimia

in trays for nurseries. So they built their own, and formed the company Conic Systems. The machine—rapid, efficient, and cost effective—has helped nurseries for food products and forestry for more than 20 years.

But in the past two years, the company's engineers have incorporated dramatic improvements to the seed-sowing technology to create the first fully automatic seeding machine.

Seeds come in significantly different sizes, and so trays, holes, and the machine's settings must be changed to switch from, for instance, onion seeds to the larger cucumber seeds. Today all these changes and adjustments are done by hand, a time-consuming process. Now Conic Systems engineers have developed a new machine that employs advances in computer technology to allow all changes to the settings to be made using a touch screen.

This took significant in-house creativity. "The commercial computers available in the market, the ones that would be able to do what we need, are very expensive," says Jordi Gusi, director of sales. "So we began to make our own hardware for the kinds of things we need the machine to do: to change the tray, the way the machine is moving, the height and width." The new system is about 20 percent faster than the previous one, and reduces the frequency of errors.

To facilitate maintenance, the seeder machines can be connected by the Internet to Conic System's offices, so the company can diagnose any problem remotely —whether it's in South America or China or Australia—and provide detailed repair information. The first prototypes have recently been completed: one will be installed for a client in Barcelona, another in Israel.

As plants grow, farmers make use of sprayers and dusters, such as those created by Goizper, to apply nutrients and protection. Goizper, which sells manual sprayers in more than a hundred countries, created a research center that focuses on developing technologies for different types of spraying needs and on improving the physical components of its systems. "For instance, 95 percent of the products we fabricate are made from plastic, so for us a very important technology—and one we're working on a lot—is the technology for the manipulation and transformation of plastic," says Mikel Irizar, director of research and innovation.

Once seeds grow and the resulting fruits are ripe for picking, the work of Tecnidex begins. One of the company's specialties is the application of the appropriate combination of gases and temperature, either to ripen fruits and vegetables or to improve their appearance (changing, for instance, the peels of ripe but green-hued citrus to the more recognizable yellows and oranges). Tecnidex developed one of the first systems to eliminate unpleasant tannins in persimmons, which are picked before they're fully mature, allowing the fruit to be more easily exported.

The company has also developed water-cleaning technology especially designed to remove the fungicides used in treatment of produce after it's picked and before it's shipped. And it is using its expertise in modifying the atmosphere of a treatment room to attempt to eliminate the Mediterranean fruit fly. Current systems for killing the fruit flies, says business manager Valentin Turégano, require very low temperatures that can "injure the internal and external quality of the fruit. So we're

trying to develop a solution that will benefit the customers and the importers of the fruit in the market."

Water is the primary concern of Murcia-based Azud, a company which has spent three decades manufacturing technology for its area, one of the most arid regions in Europe—and applying its solutions around the world. Azud's success has been in the creation of technologies for the most exact application, testing, filtration, and treatment of water. Today, the company is one of the top suppliers in the world of irrigation technology, including drip irrigation.

"We're in a situation where there's...growth in ecological concerns, and increase in the cost of electricity, and a reduction in both the amount and the quality of water," says Ramon Alcaraz, Azud's business director. "And so for us, in this sector, the challenges are to always find solutions that lead to the most efficient use of water, energy, and fertilizers."

Some of the company's successful innovations have included systems for drip technologies, and a combination technology that applies fertilizer and water at the same time (a process they call fertigation); and monitoring solutions that carefully control the application of water and fertilizer. Azud's engineers and researchers have implemented improvements to filtration and irrigation systems that conserve energy by operating at lower pressure.

PACKAGED FOR CONSUMPTION

The technology behind food packaging rarely commands as much attention as the food itself. Spanish companies have been innovating in this sector, however, for decades. For instance, the Barcelona packaging company Posimat's founder and CEO Jaime Martí realized that the machinery for organizing plastic bottles to be filled was not as efficient as it could be. So in 1977 the company developed its reliable, inexpensive Unscrambler, which funnels loose, light plastic bottles down a chute so they all drop down and into place upright.

From that point, the company has continued to innovate and address market needs, modifying this technology for the pharmaceutical industry, or for bottles that have their caps on the bottom instead of on the top, or for unstable bottles, such as those that have handles on the side. Posimat has continually focused on products that are noteworthy for their efficiency and simplicity, explains Maribel Rodriguez, assistant to its president, and has created machines that are easy to use and will last for years.

The packaging company Giro, in Badalona, Spain, supplies packaging materials and machinery to bundle fruit and vegetables into breathable, plastic net packaging. Unlike most companies in this field, Giro engineers both the material (the plastic net, the films, the labels) and the packaging machines as well. In recent years, the company has improved the automation of the process through a system they call GirControl Plus, so that multiple machines in a given plant can be controlled by

one computer; this also allows Giro's technicians to diagnose problems from miles away and determine any servicing needs.

Giro's latest offering is plastic netting that "speaks to the machines," says Salvador Sola, business strategy and export director, through a radio-frequency identification tag that alerts a machine to the type of material and the necessary settings for it. This dramatically speeds the process and at the same time helps to eliminate human error. The new technology was launched at the end of 2010. "The end users don't need to do anything but fill the reel of net onto the machine, and the machine is capable of knowing exactly what is loaded and performing accordingly," says Sola.

SCANNING THE CONTENTS

Olives tumble over one another, separated out into different streams by hue and shape. Multiscan Technologies was created more than a decade ago by university researchers from the Polytechnic University of Valencia, who realized that their artificial vision technology might be useful in the food sector, as a method for determining the quality of a particular product or of classifying and separating produce by color. They focused on olives—a key Spanish product—collaborating with a local Spanish olive packaging company, La Española. The machines could determine which olives were ripe by their color, and separate those for packaging.

"The first machines functioned quite well, and so La Española proposed that we create a company and commercialize the machines—even to their competitors," says Álvaro Soler, Multiscan's general manager.

At the time, the olive sorting machines on the market could only categorize types of olives roughly and moved quite slowly, about 2,000 kilos an hour. The new Multiscan machine could, through artificial vision technology, separate out the best olives with greater precision and at a speed 10 times as fast, at 20,000 kilos an hour.

Today's machines can manage millions of olives an hour, as much as 30,000 kilos. That is in large part because of improvements in computer speed, together with the development of proprietary software that allows the machine to make decisions at lightning speed.

"So we're no longer just classifying the olives by color," says Soler, "but now we're also able to rapidly classify them … by their form, by visible defects, even utilizing technology to detect internal defects." The machines' artificial vision employs infrared and ultraviolet light, lasers, and x-ray technologies, to get the maximum amount of information about a particular product as it passes through.

But the knowledge the company had accrued—how to distinguish among very small objects at a speedy pace—was not applicable only to olives. "We realized that we're actually specialists in managing small, round objects, so we entered the U.S. market by applying our technology to cherry tomatoes," continues Soler. Today the company exports more than half of its machines to

Multiscan is a specialist in using artificial vision to classify and separate small food products such as olives or macadamia nuts.
Photo Courtesy of Multiscan

process cherry tomatoes, macadamia nuts in Hawaii, and other products throughout South America and Europe.

Multiscan is now focusing on improving x-ray technology for quality control, to scan inside, for instance, bottles of olives to detect whether perhaps a pit escaped notice, or a bottle is contaminated with a stray piece of plastic. With such advanced technology, and with their experience in rapid evaluation of information from various information inputs, in 2010 the company expanded its artificial vision product line from food into the realm of security, developing a machine to detect explosives in hand luggage. These machines are being sold by the Spanish multinational Indra.

"We've developed a high-resolution machine that can operate 10 to 100 times more rapidly than current technology, and costs 10 times less," says Soler.

All these innovations in machinery for the food sector, says Victor Alves, director of the Spanish Association of Machinery Technology, which represents a number of different food industry associations, "help customers reduce their costs, and reduce their consumption of resources for a smaller impact on the environment… These companies design products that increase the value of food products" around the world.

Learn more at www.technologyreview.com/spain/food

COMPUTING

Smart Cubes

FITTED WITH three-axis accelerometers and short-range wireless transceivers, these blocks can sense the location of other blocks and recognize when they're being moved. This makes their color displays well suited for games. Pushing two blocks together might let a game character jump from one screen to the next, or shaking a block could make it generate tiles for a puzzle game in which points are scored when the blocks are arranged to form a particular pattern.

■ **Product:** Sifteo cubes **Cost:** $150 **Availability:** Now **Source:** www.sifteo.com **Company:** Sifteo

BRUCE PETERSON

Guerrilla Gear

THIS BACKPACK is designed for journalists working in locations that are unsuitable for a conventional news van. It lets users stream HD video over 3G, 4G, Wi-Fi, or Wi-Max connections. For lower-bandwidth cellular connections that can handle an HD stream, it splits the video feed across as many as six lines. Video is reconstructed at a data center and can be streamed back to a television studio or directly to the Internet.

■ **Product:** LiveStreamPac
Cost: $30,000 to $40,000
Availability: Now
Source: www.meshtv.com
Company: ATCi

Smart Bulb

NEW TECHNOLOGY is bringing the smart grid down to the level of the light bulb, giving each bulb its own Internet address. Connected wirelessly to the network, such lights could be monitored and controlled from any Internet-enabled device. For example, when a smart meter reported high electrical demand, unneeded lights could be turned off or dimmed to save energy.

■ **Product:** Intelligent Lighting Solution **Cost:** Not available **Availability:** Fall 2011 **Source:** www.greenwavereality.com
Companies: GreenWave Reality, NXP Semiconductors

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BIOMEDICAL
A Gentler Reveille

THIS ARMBAND measures the wrist motion of a sleeping user and transmits the data to a smart phone over a Bluetooth connection. An application on the phone analyzes the motion and determines when sleep is shallowest. An alarm can then wake up the sleeper at the optimal moment within a preset window of time, such as between 7:30 and 8:00 A.M.

■ **Product:** Wakemate **Cost:** $60 **Availability:** Now **Source:** www.wakemate.com **Company:** Perfect Third

COMMUNICATIONS
Heavy Lifter

THE PRIVATE COMPANY SpaceX is now booking flight slots for the Falcon 9 Heavy, scheduled for its first flight in 2012. Intended to carry satellites or unmanned interplanetary spacecraft, the rocket is designed to put as much as 53,000 kilograms into orbit, making it second only to the Apollo-era Saturn V in payload capacity.

■ **Product:** Falcon 9 Heavy **Cost:** $80 million to $125 million per payload **Availability:** 2013 **Source:** www.spacex.com **Company:** SpaceX
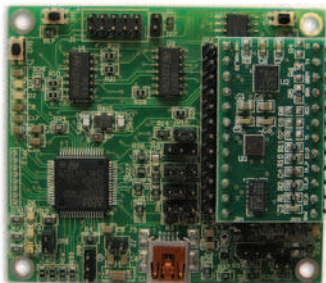
COMPUTING
Satellite-Free Navigation

THIS SYSTEM, intended for phones and other mobile devices, can determine location in the absence of GPS or Wi-Fi signals. A dedicated processor combines input from three sources: a gyroscope, a sensor that measures Earth's magnetic fields, and a silicon-based air pressure sensor that estimates altitude. This allows the processor to use dead reckoning to estimate the device's position relative to its last good GPS or Wi-Fi fix.

■ **Product:** 10 DoF sensor (evaluation board shown) **Cost:** $5.90 (in volume) **Availability:** Late 2011 **Source:** www.st.com **Company:** STMicroelectronics

Name
Dr. Dave Barrett

Job Title
*Professor,
Mechanical Engineering*

Area of Expertise
Robotics

LabVIEW Helped Me
*Bridge the gap between
teaching theory and real-
world design experience*

Latest Project
*Building a robotic tuna
to swim across
the Atlantic Ocean*

NI LabVIEW

LabVIEW makes me better by making complex

CONTROL

simple and accessible

COMPUTING

Polarized 3-D

THIS LAPTOP can display 3-D content without requiring the user to wear special glasses. The computer's Web camera tracks the location of the user's face, and then the surface of the display is polarized accordingly to deliver separate images to each eye. Regions of the screen where no 3-D content is playing are left unpolarized.

■ **Product:** Qosmio Notebook
Cost: $1,900 **Availability:** End of 2011
Source: www.toshiba.co.jp **Company:** Toshiba

COMMUNICATIONS

For Your Ears Only

THE BLUEARMOR 100 guards against hackers who use Bluetooth headset connections to eavesdrop on calls or access data stored on phones. It scrambles the wireless link using 128-bit encryption, making it the first phone headset to meet the U.S. Department of Defense's security standards.

■ **Product:** blueArmor 100 **Cost:** $200
Availability: Now **Source:** www.securebluetooth.com
Companies: Steel Cloud, Biometric Associates

ENERGY

Top Gear

OUTSIDE a small group of enthusiasts, motorcycle riders have shown little interest in electric bikes. This is largely because these vehicles have had fixed gearing that provided either good acceleration but a poor top speed or a good top speed but poor acceleration. The Engage electric motorcycle uses a six-speed mechatronic transmission that allows for both rapid acceleration and a high top speed, which could give it broader appeal.

■ **Product:** Engage **Cost:** $10,000 to $12,000 **Availability:** Spring 2012 **Source:** www.brammo.com **Companies:** Brammo, SMRE Engineering

COMPUTING

Radio Pictures

THIS MEMORY CARD for digital cameras can wirelessly upload files directly from the camera to an iPhone, iPad, or Android mobile device—even in a place where no Wi-Fi network is available, like the beach. An application on the mobile device allows images to be transferred to a device up to 30 meters away via the memory card's built-in Wi-Fi radio.

■ **Product:** Mobile X2 **Cost:** $80 **Availability:** Now **Source:** www.eye.fi **Company:** Eye-Fi

COMPUTING

The Web Is the Computer

BUILT AROUND Chrome OS, Google's cloud-based operating system, this laptop (and a similar one made by Samsung) has been stripped down to little more than what's required to run applications through a browser. There's no hard disk, for example (although a small amount of solid-state storage is available). In return, users should be able to start surfing the Web over a Wi-Fi or 3G connection within eight seconds of powering on, and the battery should last eight hours.

■ **Product:** Acer Chromebook **Cost:** $350 **Availability:** Now **Source:** www.google.com/chromebook **Companies:** Google, Acer, Samsung
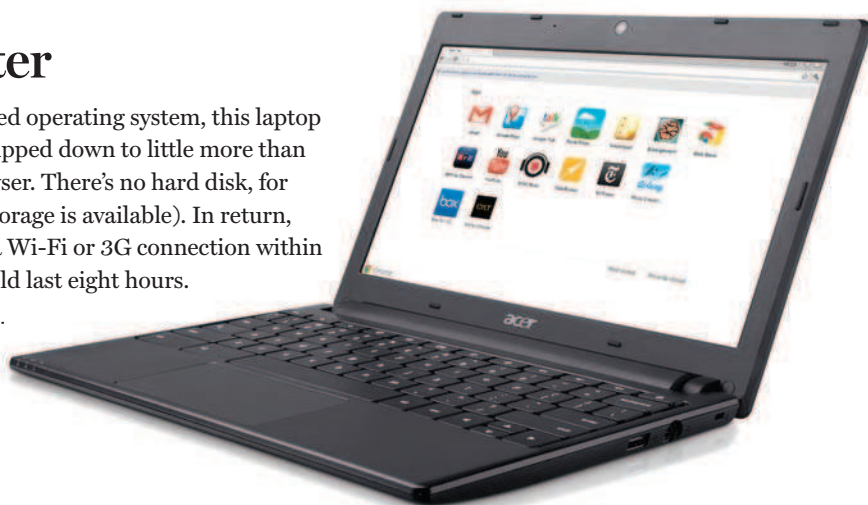
Name
Hector Guajardo Betancourt, Certified LabVIEW Architect

Job Title
Automated Test and Control Engineer

Area of Expertise
Manufacturing Test

LabVIEW Helped Me
Reduce test time by more than 10X

Latest Project
Building a vision-based inspection system for washing machine drums

NI LabVIEW

LabVIEW makes me better because I can deliver multiple

PROJECTS

on time, on spec, and on budget

NATIONAL INSTRUMENTS™

graphiti

MATERIALS

- Lithium
- Rare earths
- Cobalt
- Germanium
- Selenium
- Platinum group
- Indium

Material World

The future availability and cost of important emerging technologies could depend on access to a handful of critical elements.

Wind turbines, electric vehicles, light-emitting diodes, flat-screen displays, and solar panels all rely on elements that are mined and refined in just a few countries and traded in small quantities. Demand for many of these elements is expected to grow rapidly as these technologies become more commonly used, and impending supply constraints could hold back their growth.

As the wind-power industry expands, for example, demand for the rare-earth element neodymium, a crucial ingredient in the high-strength magnets used in wind turbines, is projected to outstrip supply by 16 percent in 2014. (China controls 97 percent of global production of rare-earth elements.)

The demand for lithium could quadruple as the number of electric cars on the road increases. The battery in every electric car contains several kilograms of lithium, the production of which is concentrated in Australia and a few South American countries. Likewise, demand for indium is expected to grow as sales of solar cells and flat-panel displays rise.

The production of several critical elements by country, as well as total production over time, is shown at right.

—Mike Orcutt

PERCENT OF 2010 GLOBAL PRODUCTION

100%
50%
25%
10%
1%

Sources: U.S. Geological Survey; Johnson Matthey; British Geological Survey.

Some percentages do not add up to 100 due to rounding. 2010 global production figures are estimates. U.S. production figures for selenium and indium are withheld. The historical production of lithium refers to lithium ore.

Map data

Canada: 3%, 8%, 4%, 6%

United States: 4%, 4%

Cuba: 4%

Other countries: 5%, 25%, 2%, 3%, 4%

Colombia: 0.3%

Peru: 2%, 4%

Brazil: 0.7%, 0.4%, 2%, 1%

Chile: 35%, 3%

Argentina: 12%
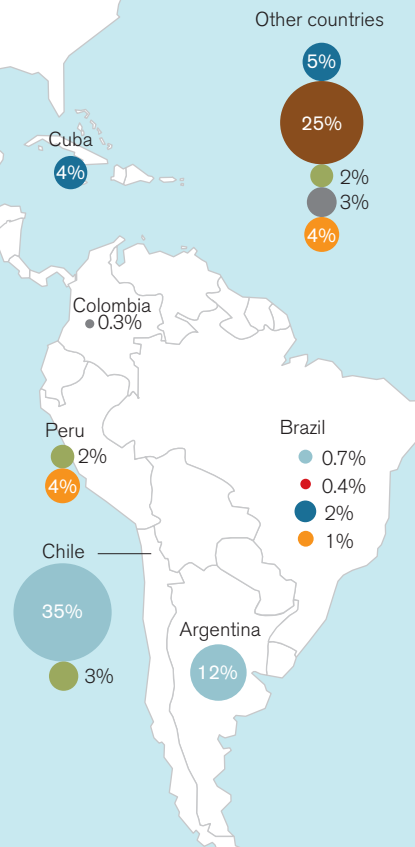
GLOBAL PRODUCTION (1970–2010, metric tons)

Lithium — 405,000   '70 — '10

Rare earths — 13,000   '70 — '10

Cobalt — 88,000   '70 — '10

Germanium — 120   '70 — '10

Selenium — 2,260   '70 — '10

Platinum group — 445   '70 — '10

Indium — 574   '70 — '10

Germany 30%

Finland 3%

Russia 7% 4% 6% 29% 1%

South Korea 14%

Japan 35% 12%

Belgium 9% 5%

Morocco 2%

China 18% 7% 67% 52%

India 2%

Philippines 3%

Malaysia 0.3%

New Caledonia 2%

Congo 51%

Zambia 13%

Zimbabwe 2% 4%

South Africa 56%

Australia 34% 5%
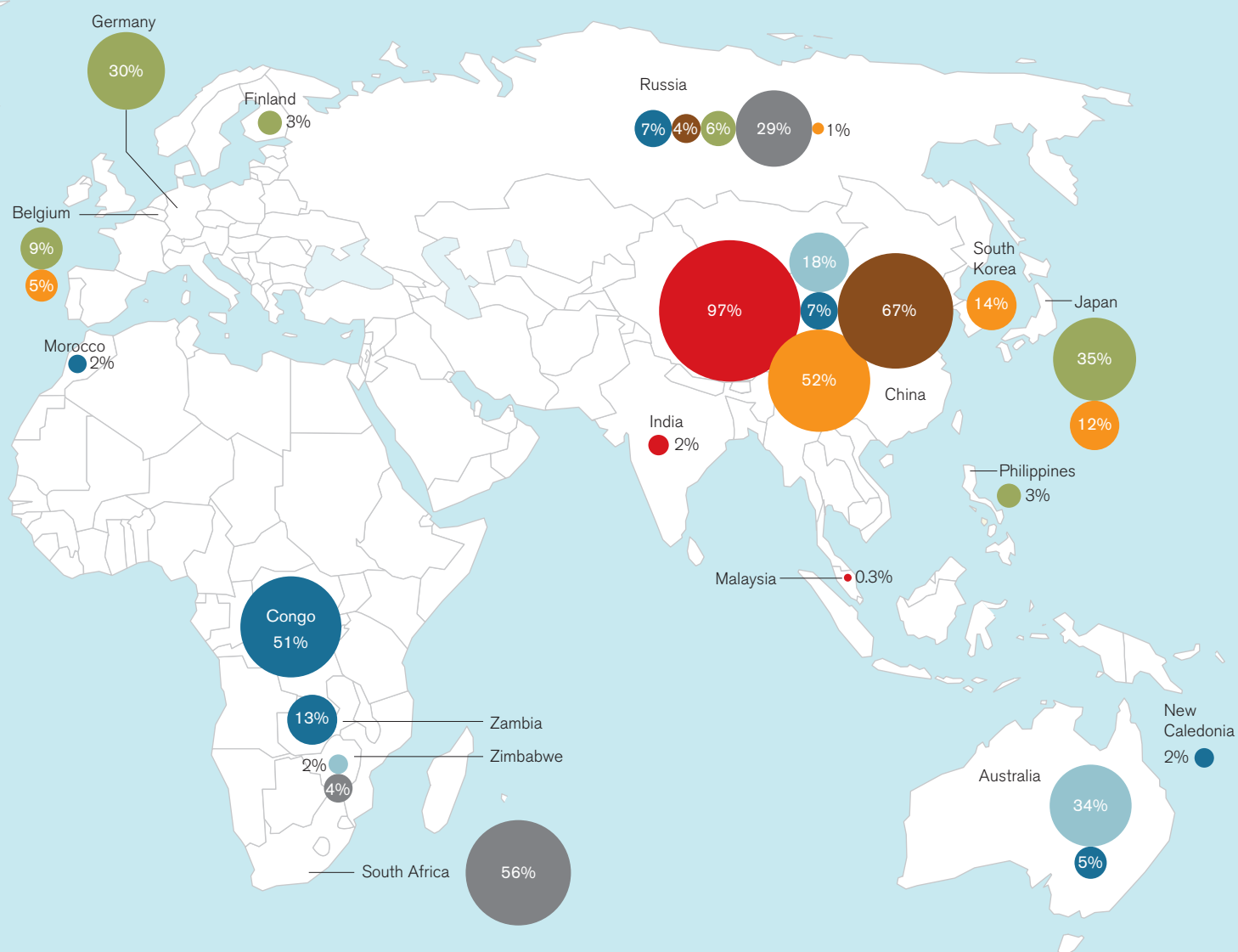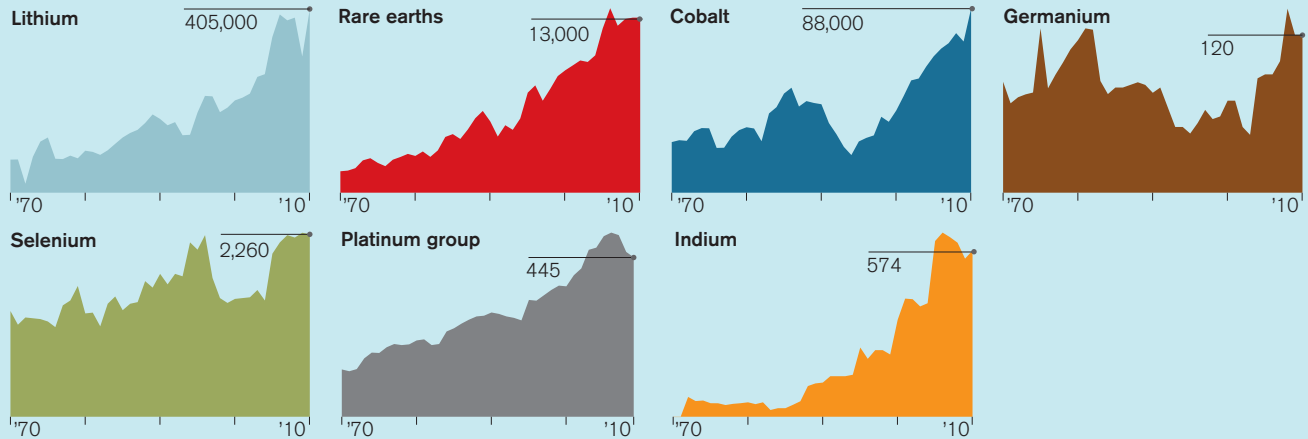
Information graphic by TOMMY McCALL *and* MIKE ORCUTT

Q&A

Nicholas Stern

The World Bank's former top economist took heat when he called for huge investments to head off climate change. Now he says he underestimated how much is needed.

The Stern Review, published five years ago this fall, framed the threat of climate change in stark, even shocking, economic terms. The 700-page analysis, which was commissioned by the U.K. government and authored by Nicholas Stern, an economic adviser to Prime Minister Tony Blair and a former chief economist of the World Bank, estimated that the costs of climate change, if not addressed, will be equivalent to losing 5 percent (and potentially as much as 20 percent) of the global gross domestic product (GDP) "each year, now and forever." Hundreds of millions of people could be threatened with hunger, water shortages, and severe economic deprivation. Climate change, Stern wrote, "is the greatest market failure the world has ever seen."

The report concluded that staving off such crises would require immediate investments equivalent to 1 percent of global GDP over each of the next 10 to 20 years, before the window of opportunity to mitigate the biggest impacts of climate change closes. And it argued that governments need to set a price on carbon dioxide emissions, through either a tax, a trading scheme, or direct regulations.

The report received much attention from the public and from policy makers, but reaction from economists was mixed. A number criticized its methods, arguing that it improperly calculated the value of today's investments relative to the same unit of investment in the future. The seemingly esoteric debate over what economists call "discounting" has a critical implication: it greatly affects conclusions about how rapidly investments in addressing climate change need to be made.

William Nordhaus, a professor of economics at Yale University, was one of the most vocal critics of Stern's methodology, disagreeing with the Review's conclusions on the magnitude and pace of investments needed to combat climate change. Still, the Stern Review has "been enormously influential" since its publication, Nordhaus says now, and it has "sharpened my thinking about the major issues."

Stern, a professor at the London School of Economics and Political Science, now heads the Grantham Research Institute on Climate Change and the Environment. In May, *TR*'s editor, David Rotman, visited him at his home, about 100 kilometers south of London.

TR: **How has the debate evolved over the five years since the Stern Review was published?**

Stern: More people have accepted its arguments. The idea that the economics should be framed in terms of managing enormous risk has gained [acceptance] in the public discussion and the professional discussion.

The fact that climate change poses such enormous risks affects how you do the economic analysis?

Exactly. You can't assume some underlying growth story on top of which climate change is laid. It fundamentally changes the whole growth story and could indeed radically reverse growth in what is a quite short period of time—50 or 100 years. Climate change over the course of the century could create environments so hostile it would reverse development and force the movement of hundreds of millions and possibly billions of people. You have to think about making policy to manage risks of that magnitude. Since the Review, I think the idea that the scale of the risk fundamentally influences the analytic methods you must use has been increasingly understood.

How have the politics around global warming changed?

In 2005, apart from [French president Jacques] Chirac and Blair, leaders just weren't interested in climate change. Now it is a political subject around the world. If you look at how dramatically China has changed over the last two years, it's quite extraordinary. Politics in China, politics in India, have changed. In the U.S. it is highly controversial; in other countries, much less so. In the U.K., all the major political parties see that strong action is necessary. The politics have changed profoundly.

Do you think that by framing climate change as an economic problem, the Review has helped clarify the issue?

It has reduced the amount that people discuss it only in terms of "Do you want income or do you want the environment?" It has become less often expressed as a trade-off. That is a very important shift in the business world and, increasingly, in the government world.

Businesses are all looking at a carbon-constrained world—some with enthusiasm and some with worry about their own vested interests. But they are looking very hard at a carbon-constrained world and planning on that basis. There is enough intensity in the policy discussion, even though it is not won, that people making investments think about what the policy will be like in 10 years. High carbon is, in everyone's mind, quite risky now—and good, because it *is* quite risky. People think of the low-carbon stuff as risky—and there are risks because you don't know exactly how the costs will turn out. But low carbon is risky and getting less risky, and high carbon is risky and getting more risky.

You called climate change the greatest market failure in history.

It's a market failure because the price we pay for products and services that involve emissions of greenhouse gases does not reflect the costs they cause through damage to the climate. Economists like me think market systems have a tremendous amount to offer if you correct the failure by putting a price on carbon.

But in the U.S., at least, schemes for carbon pricing have failed.

I think you have to take the long view. I think it will get there in the end, but regulations are okay too. You probably need a combination of these things. We didn't go from leaded to unleaded petrol by putting a price on lead. We did it mostly through regulations.

Has technology changed in the five years since the Review was published?

Technology has moved faster than I had anticipated. We've seen tremendous progress with car technologies. Five years ago, you wouldn't have thought General Motors would be making electric cars now; you wouldn't have thought the argument now would be "How fast can you bring down the costs of electric cars to be competitive?" Wherever you look now, you have quite remarkable progress—from the most imaginative kind, like algae [biofuels] and [new types of] batteries, to engineering, just making a diesel engine much more efficient, much better. So the technology has changed faster than I had expected. I find it quite encouraging.

But carbon pricing would surely help speed up the commercialization of these new technologies.

It takes a combination of things. If you ask about market failure, then carbon pricing is the big one. It will be hard to do it without that. But I would also emphasize the importance of regulations as well. Let's not have a simplistic approach by thinking, "Set a price on carbon and the wonderful entrepreneurship processes will do the whole lot for you."

Support for R&D falls into the category of smart policies?

Yes. And support for deployment also.

The Review expresses a sense of urgency about the next five to 10 years.

That's one place where I think our arguments have not been successful enough: to get people to realize just how important the next five and 10 years are. If we wait until people really start to see the full horror of severe climate change, it will be very difficult to pull out. And that is where the great challenge in communication lies.

Is there a point where if things haven't ramped up, you would become discouraged? Is there a deadline for action?

I think action has to accelerate now. China is accelerating its effort. It's quite remarkable. They have seven key industries which [its leaders] are marking to grow from 3 percent of the economy to 15 percent in the next 10 years. And the economy itself will likely double, from $6 trillion to $12 trillion. The investment they will need to do that is probably a half a trillion a year for each industry. Three of these industries are renewables, energy efficiency, and clean technologies. Why? Because [the leaders] see China as extremely vulnerable to climate change, they see China as big enough to affect its own future on the climate side, and they see these industries as growth stories in the future. A remarkable change, and it is not just in China. But I still worry that it is not fast enough. We have to accelerate.

How has the science changed since the publication of the Review?

The science looks more worrying. There are some very nasty feedbacks [that are increasing the pace of climate change] that we left out five years ago because they are very difficult to model. A lot of the drivers seem to be bigger and faster, and the feedback loops even more worrisome.

Given that, how would you change the findings of the original report?

I suspect that I underdid the costs of the impact of unabated climate change. I suspect, looking back, you would want to argue that the risks are a good deal greater. And because of the rapid technical progress, the costs of action may be a bit lower. But I don't want to suggest that it is an easy no-brainer decision. You have to make big investments now to manage the risks in the future and lay the foundation for low-carbon growth.

The Review estimates that it would take 1 percent of GDP annually to mitigate climate change.

I would up that now. I would say 1 to 2 percent now, because I think we have to act more strongly than I suggested in the Review, because the risks are bigger. But I would emphasize that for that 1 to 2 percent of GDP, we get not just risk reduction but tremendous innovation, creativity, learning, and discovery.

What does 1 to 2 percent of GDP mean? Will people feel the pain?

The investment is significant, but it's not that difficult to see why it is needed—particularly when you recognize that growth is likely to accelerate over 10 to 15 years as these learning processes kick in. And, of course, it is a very important point that the time to do your long-term investments is at a time of slack in the economy. There is less pressure on resources, and interest rates are low. Now is the time to start investing in some of these grid structures and other infrastructure.

But can we afford it?

It is an investment. You have got to recognize it as an investment, which it is. And now is the moment to make those investments. You can't afford not to make those investments: the risks are too great, and the rewards are high if you do. **tr**

INNOVATIONS IN ISR:
INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE

A soldier straps on an exoskeleton that extends along the sides of his legs and supports his 200-pound pack; immediately his pack feels weightless. A rugged hand-held computer can withstand rain, extreme heat and cold, and sudden drops, allowing military personnel to communicate with one another on the battleground. A new radar technology enables soldiers to peer through walls to determine if anyone is hiding on the other side.

These are a few of the latest innovations for the military coming out of top international companies housed in Florida. Many are clustered in the continually developing field of C4ISR—Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance. These projects and companies provide tens of thousands of jobs and billions of dollars in federal grants to the state, and endless opportunities for technological innovation.

Built to Last

Soldiers in the field who must work outside their vehicles have been requesting computers that are small, lightweight, and rugged, says Gary Eppley, project manager for Warrior Systems at General Dynamics C4 Systems, which has operations at Orlando and Sunrise, FL. General Dynamics has decades of experience producing computers sturdy enough to withstand rain, heat, cold, and all the general kinds of knocks that occur during combat. Their most recent challenge required making such a machine small enough for soldiers to slip into a pocket, wear on their chest, or strap to a wrist.

In August 2010, General Dynamics released the GD300, a light, wearable, rugged computer. It weighs just eight ounces and can withstand high humidity, vibrations, and shocks, and it runs apps useful to military personnel. When the GD300

Source: General Dynamics

is connected to a tactical radio, soldiers enjoy secure networked connectivity with each other and their leaders. Beyond the military, this product has potential for other users who need rugged devices in extreme environments, such as search-and-rescue teams, field medics, and FBI border patrol forces.

A Feel for the Operation

The engineers at Melbourne, FL-based Harris, an international communications company, are also focused on transmitting information: not just visual information but even sensory data. In a defense project the company is developing, Harris is using haptic (tactile feedback) technology to create "exquisite feedback," says R. Kent Buchanan, vice president of engineering at Harris's Government Communications Systems Division. "You can feel the tension, such as if you're pulling on a wire to disarm [a bomb]," he says. This would be useful, he explains, if someone needed to do precision work such as bomb disposal or medical procedures at a great distance or in a dangerous setting.

Design Interactive in Oviedo, FL, has designed a system that provides a touch-based language for silent communication, with a 56-element grammar that can be received and understood by feel. The company's president, Kay Stanney, reports

that the system was recently tested by soldiers on simulated patrols in Thailand. The soldiers were able to respond effectively to commands received by the touch-based system, with an average comprehension of between 90 and 100 percent. Stanney says this technology promises to be useful in urban war settings like Kabul, where soldiers must sometimes use silent communications.

Wall-Piercing Vision

Soldiers and law enforcement officials alike would love to be able to increase their surveillance abilities to determine whether someone is lurking behind a door or wall. And now, thanks to a technology developed by Orlando-based L-3 Communications CyTerra, they will be able to do so. This prototype, slightly larger than a brick, works by means of radar technology and electromagnetic waves. The waves pick up subtle changes in movement, even movements as slight as those made by a person breathing. From 65 feet away—across the street—a user holding this battery-powered device can aim it at a building and determine whether anyone is inside.

The device cannot yet do more than represent a person as a blinking dot: it doesn't yet indicate height (or even differentiate between people and animals), or show whether the target is armed. Even so, it provides information that could save soldiers from hostile combatants, or prevent civilian casualties and fratricide (the killing of fellow combatants).

Download the *Innovations in ISR* white paper to learn more about

- innovations in port security
- augmented cognition for training
- weight-bearing exoskeletons

The French consortium Novarka will construct a 100-meter-tall structure near the ruined reactor building (in background), then slide it over the building to encase it. The rebar cage in the foreground will form the basis for a concrete foundation that will support one of 19 towers used to lift prefabricated parts into place during construction of the containment building.

VOLODYMYR SHUAYEV

Nuclear Cleanup

In the 25 years since the explosion at Chernobyl, it's been a constant struggle to confine radioactive materials at the site. After years of ad hoc efforts, work has started on a massive $2 billion structure designed to seal the site for 100 years. The ruins will be dismantled with remote-controlled equipment, preparing them for permanent storage at a future site. *Technology Review* looks at what it takes to clean up a nuclear disaster over the years.

By KEVIN BULLIS

1986

In the months after the explosion, Soviet authorities organized a construction project that involved remotely operated cranes and almost 100,000 workers. They erected a temporary concrete-and-steel structure to enclose the reactor, even as experts speculated on the possibility of another explosion. The red walls seen here beneath the looming cranes are the beginnings of the structure, which came to be called the sarcophagus.

1986
The explosion scattered highly radioactive chunks of graphite from the reactor's core over the roof of an adjacent building. Here, a worker scoops up a piece of the hazardous material. Protective lead sheets are tied to his clothes. To avoid radiation poisoning, workers limited their shifts to less than a minute each.

1997

Light streams through gaping holes in the makeshift sarcophagus in this view from inside the ruined reactor building. A project undertaken to seal these holes against escaping radiation, and to prop up the walls of the sarcophagus, was finished in 2008. The ruins inside the sarcophagus remain vulnerable. If they collapse, it could become impossible to move buried radioactive materials to a permanent storage facility.

APRIL 2011

The last Chernobyl reactor, number 3, wasn't shut down until 2000. The 20,000 containers of spent fuel that had accumulated over the years must be kept cool to avoid a fire that could release radiation. Today, most of the fuel is stored in water under the metal plates in the facility seen at left. Tubes containing the fuel are visible in the foreground. (Some of the fuel is still stored in pools at the reactors.) As part of the remediation project, the fuel will be moved into more stable steel-and-concrete casks, which will be slid into the structures shown above. The casks are meant to store fuel safely for 100 years.

The Measured Life

Do you know how much REM sleep you got last night? New types of devices that monitor activity, sleep, diet, and even mood could make us healthier and more productive.

By EMILY SINGER

O n a quiet Wednesday night in April, an unusual group has assembled in a garage turned hacker studio nestled in a student-dominated neighborhood outside Boston. Those gathered here—mostly in their 20s or 30s and mostly male—are united by a deep interest in themselves. They have come to share the results of their latest self-experiments: monthlong tests of the Zeo, a consumer device designed to analyze sleep.

The group is part of a rapidly growing movement of fitness buffs, techno-geeks, and patients with chronic conditions who obsessively monitor various personal metrics. At the center of the movement is a loosely organized group known as the Quantified Self, whose members are driven by the idea that collecting detailed data can help them make better choices about their health and behavior. In meetings held all over the world, self-trackers discuss how they use a combination of traditional spreadsheets, an expanding selection of smart-phone apps, and various consumer and custom-built devices to monitor patterns of food intake, sleep, fatigue, mood, and heart rate.

Of course, self-tracking is not new. Many athletes have been meticulously monitoring personal metrics for decades. And some people with chronic conditions such as migraines, diabetes, and allergies have done the same in an effort to shed light on how daily habits may influence their symptoms. But new consumer tools have made self-tracking both simpler and more rigorous, generating reams of data that can be scrutinized for patterns and clues. The new devices, along with the increasing ease of sharing data with other users through social-networking sites, mean that more and more people are finding it useful to quantify their lives. The Zeo, a $199 device based on technology that until recently required the services of a trained technician, makes it easy for users to track their sleep

SLUMBER, SUMMED
Graduate student Ian Eslick (right) uses the Zeo monitor (above) to track his sleep. The device detects brain activity through an electrical sensor in a head-band. That data is then sent to a bed-side base-station alarm clock throughout the night.

Photographs by WINNIE WINTERMEYER
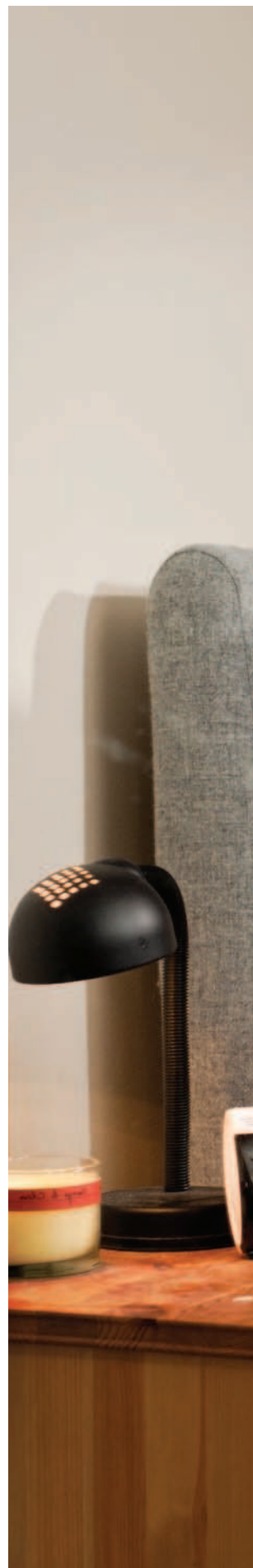
MUCH MORE THAN TIME
Julie Wilner (right), product director at Basis, uses the startup's device (above) to track heart rate, body temperature, movement, and sweat levels. The data is analyzed to determine activity levels and calories burned throughout the day. Wilner, who is trained as a nurse, hopes this daily feedback will inspire people to be more active.

cycles. The device consists of a soft head-band with a fabric sensor that wirelessly transmits EEG data to a bedside monitor. A programmable alarm clock wakes the wearer at the optimal phase of sleep. And each night's data can be uploaded to a computer, where users can study how their sleep is affected by environmental factors such as weather, light, and more.

Sanjiv Shah, a longtime insomniac who participates in the Boston group, believes that wearing orange-tinted glasses for several hours before bed makes it easier for him to fall asleep. (The theory is that the orange tint blocks blue light, which has been shown in both human and animal studies to influence circadian rhythms.) To quantify the effects, he used not only the Zeo but also a thumb-size device called the Fitbit, which incorporates an accelerometer that measures movement, and a camera trained on his bed to record his sleep for a month. His results: without the glasses, he took an average of 28 minutes to fall asleep, but with them he took only four.

The experiment has an obvious flaw: Shah knows when he is wearing the glasses, and he believes they work, so the placebo effect could be responsible for their success. Matt Bianchi, a neurologist at Massachusetts General Hospital who spoke at the get-together, says no large-scale studies have shown that orange glasses improve sleep. (By the end of the evening, plans for a group experiment to test the technique were under way.) But self-trackers say the idea

of reproducing the results in scientific tests misses the point. The glasses clearly work for Shah. And an $8 pair of plastic glasses is certainly preferable to sleep drugs as a way to gain that benefit.

As Gary Wolf, a journalist and cofounder of the Quantified Self, puts it, "It's a trial that begins with one very important person: yourself."

SELF-HACKING HEAVEN
Over Memorial Day weekend, approximately 400 hackers, programmers, designers, engineers, and health-care professionals gathered at the Computer History Museum, in the tech mecca of Mountain View, California, for the first annual Quantified Self conference. Attendees showed off fitness monitors, apps to gather and display data, and even a set of sticker sensors with embedded accelerometers to detect movement, which are designed to be stuck on toothbrushes, water bottles, or a dog's leash.

Standing out in the crowd was Alex Gilman, a researcher at Fujitsu Laboratories of America, who ambled down the main hall with a bag slung over his shoulder. A tangle of wires sprouting from it led to monitors on different parts of his body: a white plastic ear clip, which measured his blood oxygen levels; a blood pressure cuff around his arm; and a combination heart rate monitor, EKG, temperature gauge, and accelerometer strapped to his chest. The bag itself held a prototype device designed to gather and synchronize the data from all those sensors and analyze it with the help of new algorithms.

The devices are a taste of the not-so-distant future, when the monitoring tools now typical of a hospital's intensive-care unit will be transformed into wearable gadgets that are unobtrusive and effortless to use. Gilman's chest strap is from a company called Zephyr, which has traditionally made equipment to track the physiology of military personnel and emergency workers during stressful situations. Zephyr is developing simplified consumer versions of its products; the latest one tracks motion, heart rate, and respiration and includes software to assess the user's fitness level. The blood pressure cuff and the clip to measure blood oxygen, which come from different manufacturers, are still too bulky to incorporate into consumer devices. The data, however, can be integrated into a single online dashboard with the help of Zephyr software.

The new generation of devices rely on inexpensive, low-power wireless transceivers that can automatically send data to the wearer's cell phone or computer. Compared with the limited snapshot of health that is captured during an annual visit to the doctor's office, these tools and techniques could reveal the measures of someone's health "in context, and with a much richer resolution," says Paul Tarini, a senior program officer at the Robert Wood Johnson Foundation, which donated $64,000 to help the Quantified Self group create a guide to self-tracking tools.

Wearable sensors that measure vital signs such as blood pressure and heart rhythm around the clock could lead to applications we haven't thought of yet, says cardiologist Eric Topol, director of the Scripps Institute for Translational Medicine. Perhaps they could help people get a handle on health concerns such as headaches or fatigue, which don't qualify as diseases but can have a huge effect on quality of life. "People often get light-headed in daily activities," Topol says. "Is that symptom linked to an abnormal heart rhythm? Are headaches linked to abnormally high blood pressure?"

At the Quantified Self conference, the museum's walls were lined with posters describing personalized dashboards and other apps for collecting and aggregating data. But tools for analyzing the data are much harder to come by. That's why Gilman and collaborators at Fujitsu built the device in his shoulder bag. One application they've developed is a way to use time-stamped raw data from wearable blood pressure monitors to make sure readings aren't taken when the user is active, which can yield misleading results. The new software tells the device to calculate blood pressure only when another monitor reveals that the wearer has been sitting still, as indicated by a steady heart rate.

The Fujitsu researchers are especially excited about using information collected instantaneously from the EKG to calculate heart rate variability, a well-validated indicator of stress. Taking a reading with previous instruments requires the subject to stand or sit still for several minutes, says Dave Marvit, vice president of the Connected Information Innovation Center at Fujitsu Laboratories of America. That makes it difficult to monitor stress as people go about their daily lives. Recently, Marvit tested the algorithm while moving naturally during an online game of speed chess. A graph charting his stress level in real time showed a spike as he contemplated a move to throw off his opponent's strategy, and a drop as he relaxed with the satisfaction of winning the game. "Seeing the physiological consequences of the mental state makes it much

> "Seeing the physiological consequences of the mental state makes it much more real. It's much more interesting to measure stress while you're living your life than when you're standing still."

more real," he says. "It's much more interesting to measure stress while you're living your life than when you're standing still."

BETTER MEDICINE

Perhaps the most interesting consequences of the self-tracking movement will come when its adherents merge their findings into databases. The Zeo, for example, gives its users the option of making anonymized data available for research; the result is a database orders of magnitude larger than any other repository of information on sleep stages. Given that the vast majority of our knowledge about sleep—including the idea that eight hours is optimal—comes from highly controlled studies, this type of database could help to redefine healthy sleep behavior. Sleep patterns may be much more variable than is currently thought. Zeo researchers have already found that women get less REM sleep than men and are now analyzing whether the effect of aging on sleep differs by sex. The database is obviously biased, given that it is limited to people who bought the Zeo; those people are mostly men, with ample income and presumably some sleep-related concerns. But the sample is still prob-

ably at least as diverse as the population of the typical sleep study. Bianchi, who studies a number of sleep disorders and is developing his own home sleep-tracking tool, says an individualized approach to the study of sleep may help shed light on its complexities. "I have become skeptical of sleep science and clinical trials, so I am very interested in what individuals have to say," he says.

There are plenty of reasons to believe that people sharing data about themselves can produce powerful medical insights. Patient groups formed around specific diseases have been among the first to recognize the benefits to be derived from aggregating such information and sharing it.

In 2004, Alexandra Carmichael, a longtime migraine sufferer, identified dairy and gluten as the triggers for her headaches after extensively tracking her pain and correlating it with diet and other factors. Hoping to help others find relief from chronic pain, she founded CureTogether, a social-networking site where patients can list their symptoms, the treatments they have tried, and the results they've observed. Aggregating and analyzing the information has begun to reveal broader trends. For example, Carmichael and other members of CureTogether found evidence that people who experience vertigo with their migraines are four times more likely to see their pain increase than decrease if they take Imitrex, a migraine medication that constricts blood vessels. In the near term, new members to the site can use this information to help decide which treatments to try first. In the longer term, scientists studying migraines could explore this link more formally.

Such studies obviously lack the rigor of clinical trials, but they have their own advantages. Clinical trials usually impose stringent criteria, excluding people who have conditions or take medications other than the one being studied. But self-tracking studies often include such people, so their pool of participants may better reflect the actual patient population.

A DAY IN MY LIFE

STAGES OF SLEEP

■ Wake ■ REM ■ Light ■ Deep

12 a.m.   1 a.m.   2 a.m.   3 a.m.   4 a.m.   5 a.m.   6 a.m.   7 a.m.

STEPS PER 5 MINUTES

700
600
500
400
300
200
100

12 a.m. 2 a.m. 4 a.m. 6 a.m. 8 a.m. 10 a.m. 12 p.m. 2 p.m. 4 p.m. 6 p.m. 8 p.m. 10 p.m. 12 a.m.

DAILY ACTIVITY

Very active
53 minutes

Fairly active
2 hours,
18 minutes

Sedentary
7 hours,
52 minutes

Lightly active
4 hours,
14 minutes

SKIN CONDUCTANCE

1:46 a.m.   5:13 p.m.   11:26 p.m.
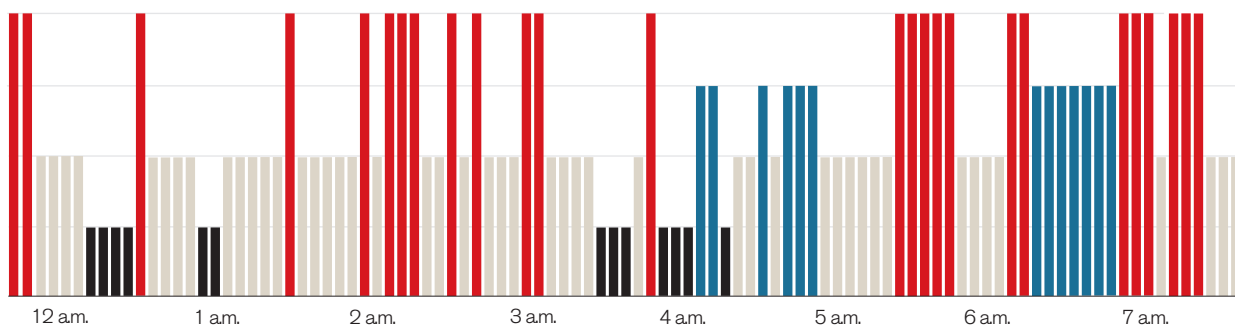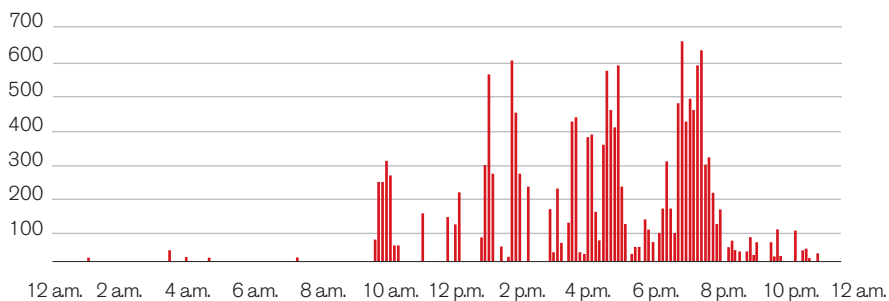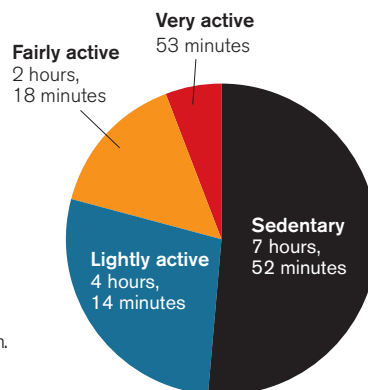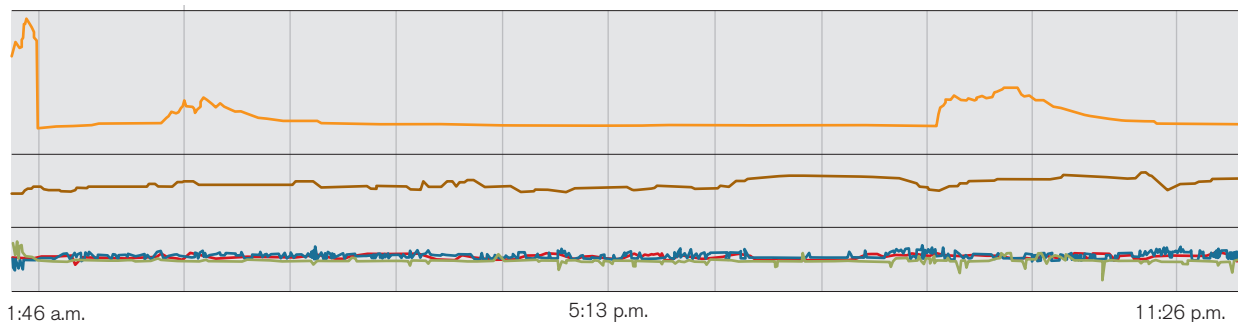
The graphs above illustrate a day in my life as documented by several of the devices that are now available to track everything from sleep to activity to stress. The top graph charts my sleep as recorded by the Zeo, revealing how many times I woke during the night. The middle section outlines the Fitbit's account of the number of steps I took over the course of the day (left) and the time I spent sedentary and mildly, moderately, or highly active. The results highlight how activity levels drop at work, even compared with evenings at home. The bottom graph shows data recorded by the Q sensor, from Affectiva, which detects skin conductance (top line), a measure related to stress, excitement, and activity. To help interpret the meaning of changes in conductance, the device also measures skin temperature (middle line) and movement (bottom lines). —Emily Singer

PatientsLikeMe, a social-networking site that provides users with tools to track their health status and communicate with other patients, has gathered a wealth of data on its 105,000 members. (The site makes money by anonymizing the data and selling it to pharmaceutical companies and other customers.) In 2008, after a small Italian study published in the *Proceedings of the National Academy of Sciences* suggested that lithium could delay the progression of ALS, or Lou Gehrig's disease, a small group of the ALS patients on PatientsLikeMe began taking the drug, and the company rolled out a number of tools to help them track their symptoms, their respiratory capacity, their dosage and blood levels of lithium, and any side effects they observed. Because the patients had collected so much data on themselves before starting the drug, researchers could analyze how their symptoms changed in the 12 months before they began taking it as well studying any changes that came after—something that's not possible in the typical clinical trial. The company published a study based on its data in April. The drug, unfortunately, was found to have no effect.

The growing availability of new monitoring devices and the increasing sophistication of social networks promise to make

The favored strategy of the moment is to weave together self-tracking tools with social networks and gaming, using the lessons of behavioral economics to keep users motivated enough to meet any health goals they've set for themselves.

self-tracking much more powerful than it was when patients who wanted to monitor their own conditions were limited to standard spreadsheets and daily logs. "We see the potential to change the power dynamics in health care," says the Robert Wood Johnson Foundation's Tarini. People could take far more responsibility for monitoring their own health. The concept of personalized medicine could change as well; rather than relying on pharmaceutical companies that have little incentive to individualize treatments, patients could simply try different interventions and record how their physiological signs and symptoms change in response.

Of course, it remains to be seen whether a movement rooted in individual experimentation can scale up in ways that will affect public health. Even if it has the potential to do so, incorporating

findings of this type into the health-care system is likely to be an enormous challenge. When you start with information from a study of one person, says Tarini, "the system doesn't have a way of determining what should be explored further." And because many of the new tools for tracking are aimed at consumers rather than the medical market, they have not undergone the rigorous testing required of medical devices. Still, Tarini is optimistic. "We have the opportunity to explore a whole new set of information," he says. "That has the potential to teach us a lot about health care."

THE BIG PAYOFF

The early adopters of self-tracking are often odd. In one breakout session at the May conference, a group earnestly discussed the results of their experiments. Standing on one leg for eight minutes a day helped one person sleep. Eating butter helped another think better. One had logged every line of computer code he'd written for a decade. But there is a far more pragmatic side to the movement, too. Across the building from the butter eater, another group, made up mostly of entrepreneurs, discussed business models for selling self-tracking apps and devices.

The favored strategy of the moment is to weave together self-tracking tools with social networks and gaming, using the lessons of behavioral economics to keep users motivated enough to meet any health goals they've set for themselves. "We want to create an engaging device that makes people want to make better health choices," says Julie Wilner, product director at Basis, a startup developing a new watch laden with sensors. "We do that by tracking data and showing it on the Web and on mobile devices, and by sharing it with friends."

Withings, a French company that makes wireless scales and blood pressure monitors, gives users the option of tweeting their weight, with the goal of adding social pressure to make people stick to a diet. (Only a small percentage of users employ that feature, and the vast majority of them are men. The company is also experimenting with delaying readings from the scale. That way, the user may be less likely to get discouraged on a bad day and stop weighing herself.) And Green Goose, the startup developing the sensor-equipped stickers for household objects, plans to create a game based on personal health goals, awarding points whenever the user walks the dog or takes vitamins.

Yet even as startups plot how to profit from the trend, the people behind the self-tracking movement have a very different mind-set—and very different goals. "I find that the most interesting tools are those that give us the chance to reflect on who we are," says Wolf, the Quantified Self founder. The problems self-tracking tries to solve, he says, are important to everyone's life: "How to eat, how to sleep, how to learn, how to work, how to be happy." **tr**

EMILY SINGER IS *TECHNOLOGY REVIEW*'S SENIOR EDITOR FOR BIOMEDICINE.

The Perfect Scam

It's the dark side of innovation: how crooks peddling fake antivirus software have gamed the Web in a billion-dollar rip-off.

By DAVID TALBOT

Not long after Prince William and Kate Middleton exchanged vows on April 29, a 1981 wedding portrait of the groom's late mother, Princess Diana, appeared as one of the top three images for people typing the most popular search term on Google that morning: "royal wedding coverage." But the link was a trip wire. Fraud artists had finagled a malicious website through Google's algorithm. The link led to a hacked page on a Web comic book called Kiwiblitz.com, which redirected the browser to another site—one with a domain name from an obscure Australian island territory and hosted in Sweden. That site displayed a realistic-looking program called "XP Anti-Spyware" that issued bogus warnings—*Your Computer Is Infected!* A few clicks led to a purported solution, for $59.95: a download of a fix that didn't actually exist.

Chalk up another success for what's generally known as the "fake antivirus" scam. Federal investigators and security experts estimate that its various iterations have extracted at least $1 billion from victims in the past several years, and it has become the most visible manifestation of an overall rise in malicious software, or "malware," distributed online *(see charts, p. 51)*. The damage goes beyond the theft of cash: even if you don't pull out your wallet, sometimes merely clicking on the bogus come-ons can deliver other forms of malware that may steal your passwords or conscript your computer into a remotely controlled gang called a botnet. Because it generally relies on fooling people into voluntarily installing malware—a strategy called a social-engineering attack—it can wind up infecting even well-maintained machines, both PCs and Macs. "As a human-level act of deception, it is just classically beautiful," says David Clark, a research scientist at MIT's Computer Science and Artificial Intelligence Laboratory, who was the Internet's chief protocol architect in the 1980s.

This threat is a product of nimble technology and a business model that rewards innovation. Con artists have rendered thou-

sands of variants on the fake-antivirus lure in dozens of languages, devised automated means of infecting ordinary websites, and dreamed up many "vectors," or methods of delivering Web links bearing their nefarious payload. Gamed search results are only one method. Online ads are another vector, as are spam e-mails, links on social networks, and even robo-calls via Skype or telephone advising people to visit websites that belch up the attack. "It's a really dominant threat to computer users that has persisted over time and continues to evolve and grow," says Maxim Weinstein, director of StopBadware, a nonprofit in Cambridge, Massachusetts, that helps websites rid themselves of malware hacks and pushes to shut down malicious sites. The success of the scam exposes the flat-footedness of many of the Internet's major players, which have been unable to coördinate a strategy for dealing with it.

There have been victims in at least 60 countries. "I spent hours cleaning up a system that got infected because an employee clicked on one of these warnings," says Brian D'Arcangelo, information technology technician at Lynn Community Health Center, in Lynn, Massachusetts. "It's happening with greater frequency here." A jewelry maker in Toronto—who wanted only his last name, Moser,

"The criminals are doing a better job coördinating their offense than the good guys are doing coördinating our defense," one researcher says.

used—found his Windows PC locked down with blinking warnings last year after he searched for items related to his trade, so he went ahead and bought the "solution" for $79.95. He had to get the computer cleaned. Searches for terms as mundane as "balloons" have led to attack sites. Apple forums have been lighting up with pleas from customers seeking to extricate themselves from scams like one urging them to buy nonexistent "Mac Defender" software. The mother of Melissa Hathaway, who served as President Obama's cybersecurity adviser in 2009, clicked to install a fake antivirus product last December. Computer security experts warn that many victims don't even realize they've been scammed.

ECONOMICS

The appeal of the bogus antivirus software—often called "scareware"—is rooted in fear. This fraud doesn't rely on convincing the victim of something preposterous—for example, that a Nigerian prince needs help relocating his money. Instead, the delivery is calibrated to capitalize on the real warnings we've all gotten. "People

who don't know exactly what's going on—and have been [told], 'Run your antivirus protection, brush your cyber-teeth every day'—are going to be driven to try to respond to that," says Vint Cerf, a coinventor of the Internet's original protocols, who is now chief Internet evangelist at Google. The attacks generally come from countries where cyber-crime laws are lax (or unenforced) and treaties obligating coöperation with other nations are not in effect. Many criminal gangs operate networks from Eastern Europe in particular. (Some malware checks to see whether a potential victim's computer is set for Eastern European locales or has a Russian-language keyboard, whereupon it will gracefully exit.)

It's easy to see why the fake-antivirus scam is so popular among criminals. The payoff is immediate and the profits large. Someone who steals other kinds of digital booty, like credit card numbers or passwords, must take extra steps to cash in. But a fake antivirus product puts money right into the crook's pocket. For example, in 2008 the U.S. Federal Trade Commission sued principals of Innovative Marketing, which was incorporated in Belize and at the time maintained offices near Kiev, Ukraine. The FTC said the company hauled in more than $163 million from 2004 to 2008 by tricking consumers into clicking to download fake software with such clever titles as Winfixer, WinAntivirus, Drivecleaner, SystemDoctor, and XP Antivirus 2008. Last year a federal judge in Maryland levied a judgment in that amount against company principals Shaileshkumar "Sam" Jain and Bjorn Daniel Sundin, who were later hit with wire-fraud indictments in federal court in Chicago. They remain at large. A third defendant, James Reno of Amelia, Ohio—who had settled with the FTC—was also indicted; he is accused of running a call center where operators tried to fend off people who complained, though the staff also sometimes provided refunds to irate customers in order to stay off the radar of credit card companies. His attorney did not return messages left by *Technology Review*.

The damage wrought by this organization may have been even worse than the FTC alleged. A researcher for the security company McAfee was able to determine that Innovative Marketing had some 600 employees and 34 servers disseminating malware, most of them operating from a traditional office complex in Kiev. The corporate empire included divisions that handled credit card payments, the call center in Ohio, and several adult websites that did double duty as vectors for the fake antivirus software. McAfee noted that Innovative Marketing logged 4.5 million orders during an 11-month period in 2008; at $35 per order, the annual revenue apparently neared $180 million. That's better than the $150 million that Twitter will pull in this year, according to an estimate by the market research firm eMarketer.

Innovative Marketing no longer exists. But that hasn't slowed the worldwide fake-antivirus business. "There have been multiple malware gangs working rogue antivirus scams consistently over the

AT LARGE Shaileshkumar Jain (above left) and Bjorn Daniel Sundin (right) have been charged with wire fraud and hit with a $163 million judgment after allegedly bilking consumers by selling fake antivirus products through their now-defunct company Innovative Marketing, which was based in Kiev. With global malware gangs keeping the scam thriving, phony warnings similar to the one at right—in dozens of languages—are a familiar sight to millions of computer users worldwide.

past five years," says Eric Howes, research analyst at GFI Software, in Clearwater, Florida. To keep the operations humming, purveyors of this and other forms of malware adapt a business technique used by companies like Amazon: the affiliate model. Just as anyone's website can include a link to an Amazon purchase form and collect a fee for any sales, antivirus scammers enlist third parties known as affiliates, who can get a fee for each installation—that is, each time someone opens the door to malware by clicking on the false warning—plus a commission on each resulting "sale" of the phony product. One distributor, Avprofit.com, promised on its website that it would pay between $300 and $750 for every 1,000 installations in the United States, Canada, Great Britain, or Australia, where the chance is higher of encountering victims who can afford to pay what the fake warnings demand. Experience required: Avprofit sought hackers with "minimum average 250 installs per day."

Many of the affiliates do extremely well. SecureWorks, a unit of Dell, analyzed the distribution of a fake antivirus program called Antivirus XP 2008 via an outfit called Bakasoftware, which was based in Russia. According to documents provided by the hacker behind Bakasoftware, who went by the nickname Krab, one of his top affiliates was able to fool 154,825 people into installing copies of malware on their computers in 10 days, with 2,772 victims going on to enter their credit card numbers. If the documents are accurate, Krab's affiliate scuttled away with $146,524 in that brief period.

INNOVATION

Affiliates have spawned an impressive body of dark innovation to create new ways of infecting computers over the Web. A key tool is a legitimate website that has been surreptitiously compromised. If you visit such a site, you are often automatically redirected to a site that brings up the flashing warnings, attempting to fool you into clicking approval to download the fake antivirus program. Often,

other malware is seeking unpatched holes in common software like Java and Adobe Flash—holes through which it can install other damaging payloads, like malware that steals passwords stored on your computer. This is known as a "drive-by download."

Remarkable technology underlies the whole process. To maintain a constant supply of infected websites, criminals write code that crawls the Web looking for known vulnerabilities in common publishing platforms like Wordpress or in Web hosting software such as cPanel, says Weinstein. (Every month, his StopBadware organization helps clean up 1,200 websites, a tiny fraction of the hundreds of thousands believed to be infected at any time.) Alternatively, the criminals can use purloined passwords to log in to websites and add malicious code. To make this job easier, botnets do much of the work automatically.

Booby-trapping websites is just one step. The malicious code must avoid detection if those sites are to remain useful to the criminals. To outwit real antivirus programs that are updated daily, the criminals make cosmetic changes to the code—often with simple and widely available encryption tricks. (The malicious code behind the Princess Di image, for example, was much the same as that used in other fake-antivirus scams but was missed by 38 out of 42 real antivirus scanners.) And to keep ahead of the blacklists that security companies and Web companies maintain to block Web addresses known to be housing malicious software, they exploit techniques for rapidly registering and changing thousands of addresses.

A look at one domain registry shows how easy this is. A company in South Korea specializes in selling millions of addresses in the national domain ".cc"—that of the Cocos (Keeling) Islands, an Australian territory. The Korean shop has registered "co.cc." To this it can add countless numbers of names. For $1,000, in fact, it'll give you 15,000 of them. It boasts of having 57 million co.cc

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sites indexed by Google, showing just how easy it can be to reach a broad swath of victims. And free Web hosting services around the world make it easy to press these sites into service.

VECTORS

To get their links in front of victims who are likely to see and click on them, antivirus hoaxers need vectors, and they've used many: porn sites, online advertisements, search results, software traded on file-sharing sites, and links on Facebook and Twitter. Increasingly, malicious websites using these vectors are created daily or even hourly to keep ahead of efforts to block them and shut them down.

Infecting online advertising is quite simple: the bad guys buy ads and rig them with malicious code or links. According to the FTC, representatives of Innovative Marketing posed as representatives of real companies and organizations—including Travelocity, Priceline, and Oxfam International—and purchased advertisements supposedly on their behalf. Those online ads employed an ingenious variant on location-based targeting. They appeared legitimate when viewed from the IP addresses of the ad network's employees, but viewers at other addresses were redirected to fraud sites. More recently, according to a report by the security company Websense, infected advertisements—placed by ad networks that had not thoroughly checked out the clients—have shown up on Gizmodo, TechCrunch, and the website of the *New York Times*.

But search engines might be the predominant vector now, says Stefan Savage, a computer scientist at the University of California, San Diego. The scam artists play a variety of search optimization tricks to fool the algorithms that Google, Bing, and other engines use to determine which Web links to show in response to search requests. Generally, a page on an infected site (such as Kiwiblitz.com) is quietly stuffed with trendy search terms and links to images. Then the malicious players interlink pages—hundreds or thousands of them—so that the search engines' Web-crawling programs rank the infected page near the top for apparent popularity and relevance. Denis Sinegubko, a malware researcher in Russia, believes that criminals "have managed to hijack search results on the first pages of Google Image search for millions of keywords." As a result, he estimates, people clicked on poisoned image-search results 15 million times a month this past spring. Google says it has since reduced the number of malicious links in image searches by 90 percent from peak levels, and a spokesman emphasized that it continues to plug holes in its algorithms to head off new methods of attack. Google says that 0.5 percent of searches bring back returns that include at least one known malicious website. This might sound low, but given that Google handles more than a billion searches daily, it means that five million search returns every day bear a malicious link.

When Google identifies a potentially malicious search result after reports by users or security companies, it flags it with warning mes-

sages. And if a site has "gamed" the search engine and should not have been delivered in the first place, Google will remove it from the search returns. Google also reveals its list of malicious sites to Internet security companies and Web browser companies, which can issue their own warnings if you try to type in the addresses. "Our response time has gone from weeks or days to hours and even minutes," says Panayiotis Mavrommatis, a malware researcher at Google.

But the Web industry still hasn't been able to keep up with the problem. Facebook, for example, blocks its users from accessing websites on Google's blacklist and those identified internally and from other sources as malicious. Yet it and other social-networking sites, like Twitter, are still major vectors, in part because criminals set up bogus accounts or hack legitimate ones. Some 40 percent of Facebook status updates contain links; of those, 10 percent lead to spam or malicious websites, according to a November report by Websense. Mavrommatis, like other security researchers, admits that the challenge is a tall one. "With the rotation of domains, the URL-based filters become less powerful. And with content-based filters—again, encryption breaks them," he says. "That is why it is so hard."

> Google says that 0.5 percent of searches generate returns that include a known malicious website. That still translates into millions of returns for malware every day.

FLYING BLIND

Researchers say that ending the scourge of fake-antivirus malware—or malware of any other kind—will be nearly impossible unless Web and security companies collect and share more information about everything from the vectors that predominate in a given week to the banks that fraudsters are using to accept payments. Private companies reveal only limited data about breaches on their sites or malicious links in their networks. "There is surprisingly less information in the industry than you might think," says Michael Barrett, the security chief at the online payment service PayPal.

That's partly because having proprietary information about malware provides a competitive advantage for Internet security companies. "There has to be more of a community sharing effort, which the security industry is not used to doing," says Philippe Courtot, CEO of Qualys, a security company. "Since no one company can have a complete view of the attacks and of the vulnerabilities, only a broader and community-driven effort can solve the problem."

FAKE ANTIVIRUS PROGRAMS AND THE SURGE IN WEB MALWARE

Criminals are accelerating their delivery of malware over the Web, changing URLs frequently to avoid being blocked.

Reported Web addresses with malware

632,600

354,200

'10   '11

1/1/10   2/25/11
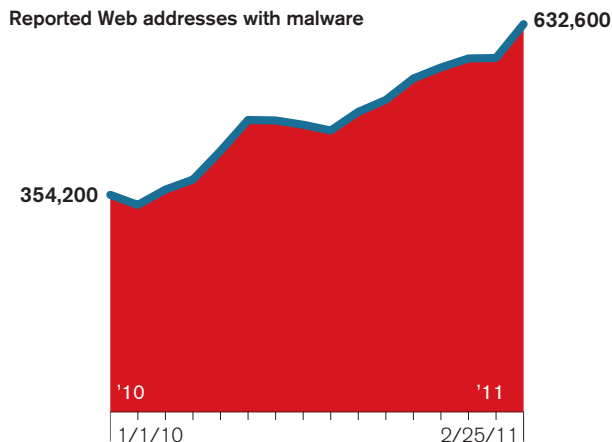
Note: Data sampled every four weeks
Source: StopBadware, based on data from Google, GFI, and NSFOCUS

To avoid detection by real antivirus updates, criminals regularly reëncrypt malware, producing a surge in varieties of it.

Discoveries of new malware signatures (in thousands)

19,814

12,397

8,379

5,918

1,023

334

'05   '06   '07   '08   '09   '10
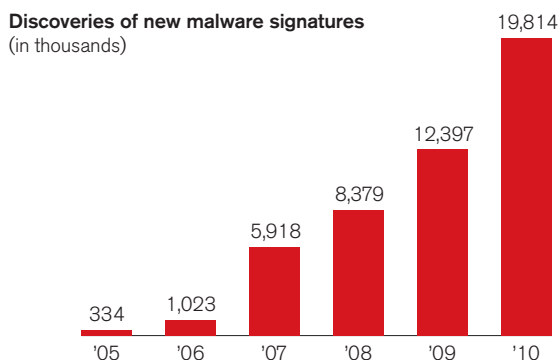
Source: AV-Test

More than 3,000 variants of fake antivirus programs have hit consumers in recent years, and the pace has increased.

Number of released fake antivirus titles (quarterly)

255

216

'05   '06   '07   '08   '09   '10   '11
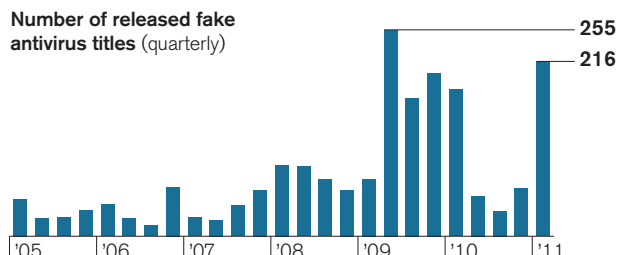
Note: Only about half of all fake antivirus titles have known release dates.
Source: McAfee Labs

Fat profits drive the phony-antivirus business, as records from a Russian malware enterprise show.

A champion fake-antivirus salesman: $146,524 in 10 days

338,159 attacks — Number of times the antivirus come-on was displayed on victims' computers.

154,825 downloads — Number of victims who clicked to download the malicious software offering.

2,772 purchases — Number of victims who went on to make a "purchase" of the fake product.

$147,116 — Total of purchases
−$592 — Less refunds
$146,524 — Total
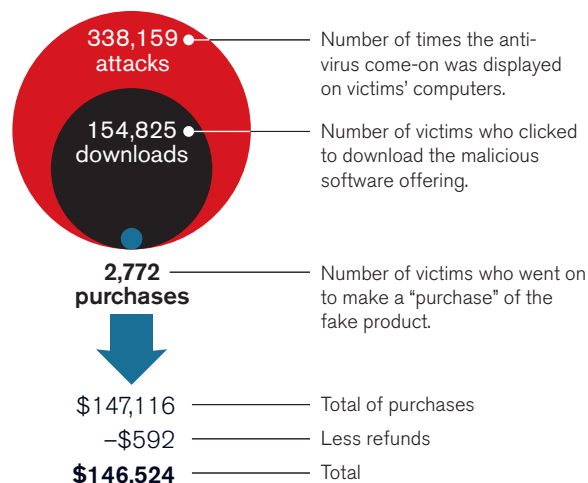
Source: Dell SecureWorks study of Bakasoftware, a Russian fake-antivirus pusher. It discovered these and other records in a Bakasoftware forum posting in 2008.

StopBadware is working on a partial solution: a reporting system to which it hopes a critical mass of Internet companies will contribute reports of infected websites. It will vet reports for accuracy, pass the information to Web hosting companies so they can take down the sites, and publicize which hosting companies aren't cracking down. Increased pressure on those companies could force the criminals to change tactics, adding costs for them.

Another way to hassle the criminals could be to more closely scrutinize the banks that process their credit card payments. Savage suggests that credit card companies and law enforcement need not target many banks to have a big impact. He and colleagues recently studied a random sample of 120 products advertised through spam and determined that 95 percent of their sales went through just three banks, in Azerbaijan, Latvia, and St. Kitts and Nevis, West Indies. Savage believes that a study of payments for fake antivirus software would yield comparable results.

Meanwhile, at any one time, at least several hundred thousand websites—*known* ones—are distributing malware through fake-antivirus and other scams. "The criminals are doing a better job coördinating their offense than the good guys are doing coördinating our defense," Weinstein says. That means the bogus flashing warnings—*Your Computer Is Infected!*—increasingly reflect the truth. **tr**

Stem-Cell Gamble

After years of controversy, a therapy based on human embryonic stem cells is finally being tested in humans. The treatment holds out hope to paralyzed people, but at how great a risk?

By ANTONIO REGALADO

Hans Keirstead wakes up every morning at his home near Los Angeles and checks CNN. He's looking for news about the first-ever human test of embryonic stem cells, launched in October by the biotechnology firm Geron. Mostly, he's looking for bad news. "If someone dies, or is in pain, then it's over," he says, pushing a hand through his tawny hair. Keirstead, dressed in a loose linen shirt and wearing a thumb ring, is a biologist at the University of California, Irvine, who has variously been called the "rock star," "miracle worker," and "Pied Piper" of stem-cell science. Today he has a corner office in a new $67 million research center paid for in part by California voters, whom he helped persuade to vote for a $3 billion stem-cell spending plan in 2004 with a video of partially paralyzed rats walking again after stem-cell transplants performed in his laboratory.

That same treatment is now being tested in human beings. No wonder Keirstead is anxious. Although he is not directly involved in the clinical trial, the discovery he patented, promoted to Californians, and later licensed to Geron has now become the leading test of whether embryonic stem cells will finally live up to their medical potential. "I'm dying to know if it works," he says.

As *Technology Review* went to press, Geron had so far treated two patients: a 21-year-old nursing-school student named T. J. Atchison, who was paralyzed at the chest in a car crash last September, and a second person who has not been publicly identified. The hope is that cells injected into their spinal cords could help mend damaged nerves and restore at least a degree of mobility and sensation. Even if the treatment fails, many researchers believe the test is a critical step toward a time when bodies are healed and regenerated with living cells, not chemical drugs. "Cell therapy is now here to stay," says Wise Young, a professor at Rutgers University and an expert on spinal-cord injury. "I tell my students that this will be the future—that they will be the first generation of doctors to use cell therapy."

Thirteen years of public debate, scientific surprises, lawsuits, and presidential decrees have gone by since embryonic stem cells were first isolated, in 1998. Stem cells drawn from early-stage human embryos have the potential to develop into any type of cell in the body. In a lab dish, they can give rise to nerves, skin, even pulsating heart cells. And Geron, a 180-person biotech outfit in Palo Alto, has promised for a decade that treatments based on the

CARY NORTON

T.J. Atchison was the first patient to be treated with a new approach to mending spinal-cord injuries. The treatment uses cells grown from embryonic stem cells.

cells could be just around the corner. The company says it spent $45 million on amassing the evidence needed to persuade the U.S. Food and Drug Administration to allow the first-of-a-kind human trial to proceed—an effort that included animal tests it calls exhaustive. "The agency told us our application was the largest they'd ever received," says Geron's interim CEO, David Greenwood, sweeping his hand over a double-length conference table that once creaked under the weight of all 22,500 pages.

Geron's success in getting the FDA to green-light the trial has already triggered a small explosion of other embryonic-stem-cell studies. Advanced Cell Technology, a smaller competitor in Marlborough, Massachusetts, has been cleared to begin two trials that will involve replacing cells in the eyes of people going blind from macular degeneration: lab workers will use stem cells to manufacture a type of retinal pigment cell that the disease kills off. Next in the pipeline is a startup company's effort to transplant lab-grown replacement nerves into infants with a fatal genetic disease called spinal muscular atrophy. That trial is planned by California Stem

ber 2006). "If they get an adverse event, there will be hell to pay," he says.

NO MIRACLE

Spinal-cord injuries cause paralysis by killing off nerves that transmit sensory impulses and leaving others stripped of their myelin sheath, the layer of fatty insulating material that helps nerve signals travel. Geron manufactures its treatment, known as GRNOPC1, by coaxing embryonic stem cells to form what are known as oligodendrocyte precursor cells. Those cells are bottled and frozen, and Geron scientists believe they may help restore some degree of sensation and limb movement to patients if transplanted soon after a spinal-cord injury. That is because oligodendrocyte cells produce myelin and may serve other purposes as well, such as encouraging new blood vessels to form. In Geron's initial human trial, designed to test the safety of the treatment, doctors plan to inject two million cells each into the spines of 10 people whose legs have been paralyzed in accidents.

Cell, which has raised $10 million from wealthy donors and has signed up Keirstead as its chief scientific advisor. Keirstead, bounding through the still empty offices with a tape measure in hand, says he is considering leaving his lab to join the company full time. He thinks that with the Geron trial now under way, other human studies can advance much more quickly and cheaply.

But that depends on what happens in the Geron trial. And even some of stem cells' most ardent advocates worry that things may be moving too fast. Arthur Caplan, a bioethicist at the University of Pennsylvania and a defender of stem-cell research (see Q&A, September/October 2006), calls the Geron study poorly designed and says it should never have been allowed to proceed. "This is nuts and hugely risky," says Caplan. "The animal studies are not adequate to justify the trial." Those studies provide too little proof of safety, he contends, and Keirstead's original findings in rats offer thin evidence that people will be helped.

Looming large is the history of gene therapy, another advanced biomedical technology, which badly misfired when a young volunteer named Jesse Gelsinger died in a safety study in 1999. Caplan, who was close to those events, sees worrisome similarities (see "The Glimmering Promise of Gene Therapy," November/Decem-

Will the treatment be a cure? The odds are against it. In general, most new treatments, never mind highly experimental ones, bomb out early. What's more, GRNOPC1 faces an uphill fight against medical dogma, which says that it's impossible to reverse damage to either the brain or the human spinal cord. That means few experts expect a miracle from GRNOPC1. Richard Fessler, a surgeon at Northwestern Memorial Hospital in Chicago who is leading patient recruitment for the Geron trial at seven U.S. medical centers, calls the study a "rational" attempt to reverse spinal-cord damage. But he cautions against expecting too much. "We wouldn't be doing this if we didn't have hope, but I don't want to instill false hope," Fessler said in a news conference in May, after the second patient received the treatment. "I'm not going to go to one of these patients and say, 'We're going to give you a transplant and you're going to walk.'"

Still, some patients are clamoring to join the Geron study, even though only people with extremely recent injuries—the kind that lab research suggests might be helped—are allowed to participate. A Dutch man offered Geron $1 million to treat his son, and Keirstead says he received an even bigger offer from a paralyzed Texas millionaire. "He said he'd pay me whatever millions it takes

A HISTORY OF STEM CELLS
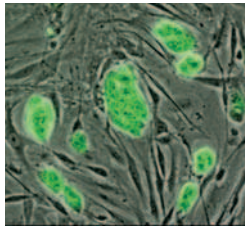
JULY 1981
Mouse embryonic stem (ES) cells are isolated.

NOVEMBER 1998
Human ES cells are isolated.

AUGUST 2001
President George W. Bush allows federal funding for ES cell research, but only on cell lines already in existence.

FEBRUARY 2002
ES cells are used to treat Parkinson's symptoms in rats, but the treatment causes brain tumors.

NOVEMBER 2004
California's Proposition 71 creates the California Institute for Regenerative Medicine to fund ES cell research with $3 billion over 10 years.

MAY 2005
Hans Keirstead publishes data from a study of paralyzed rats treated with ES cells.

JANUARY 2009
Geron receives FDA approval to begin human testing of its cell-based therapy.

MARCH 2009
By executive order, President Barack Obama reverses the Bush administration's restrictions on ES cell research.

OCTOBER 2010
Geron announces that the first human subject, a patient with spinal-cord injury, has been treated with its therapy.

to set up a clinic in Mexico, and another $2 million for me, just to treat him," he says. "It made me pause, but not for long."

One person who made a public plea to enter the trial is Michael Martinez, a 24-year-old jockey who was paralyzed after falling from a horse at San Francisco's Golden Gate Fields last year. Martinez was refused, in part because his injuries, including three crushed vertebrae, were too extensive. "He is the most challenging candidate for stem cells—if they can have any impact in him, that would be extraordinary," says David Seftel, the doctor who came to Martinez's aid at the track and has led a campaign to have him treated with stem cells. Seftel complains that the spinal-cord specialists who treated Martinez view stem-cell research with skepticism and were reluctant to get behind the idea. "We experienced a lot of resistance," he says. "We were told it's an irresponsible option to present to patients at this time. But the science only advances if people take carefully calculated risks."

With Seftel's help, and a letter-writing campaign by other paralyzed people, Martinez is now a candidate (pending Swiss government approval) to join a study in Switzerland sponsored by a California company called StemCells Inc. In that study, doctors are implanting nerve cells obtained from early-stage human fetuses; unlike embryonic stem cells, such fetal cells have already begun to differentiate into other cell types. "We have moved heaven and earth here to make sure he gets in," says Seftel. If he's approved, Martinez will travel to Switzerland for screening and then, if he passes, undergo 30 days of additional tests before being cleared to participate in the trial.

Martinez, a Panamanian who speaks little English, says he believes the operation "could help me regain sensation in my legs, and return to capacities I had before." As with most paraplegics, being unable to walk is the least of his problems. His biggest difficulty is bladder infections, since he must urinate through a catheter. Martinez says he's aware that there are dangers associated with the stem-cell treatment, but as a jockey, he's used to long odds. "I know it has certain risks, but I don't want to think about those," he says. "I want to stay focused on the positive."

TOO POWERFUL

The human embryonic stem cell was isolated in 1998 by James Thomson at the University of Wisconsin (Geron, in a farsighted gamble, funded his work). Thomson made two main scientific claims about his discovery. The first, and better known, involved the cells' capacity to differentiate into any tissue type in the body. Less well understood but equally important was that embryonic stem cells are immortal: they keep dividing, never running down as normal cells do. They are, in short, like no other human cells.

The truth of those claims is evident at Geron's one-story headquarters in Palo Alto. In its labs, the company grows not only nervous-system cells but also heart muscle, which is being transplants into 100-pound pigs, and cartilage cells that are being tested in the knees of sheep. Amazingly, all the billions of cells that Geron has grown for its spinal-cord program—including those injected into Atchison's spine—are direct descendants of the very first supply of stem cells that Thomson created from an embryo, a cell line

known as H1. "There is no further destruction of human embryos required to keep this work going, and there hasn't been since 1998," Ed Wirth, Geron's medical director, told a Phoenix audience last year. "[It's] very, very powerful how you can multiply these cells."

If anything, embryonic stem cells are too powerful. Early on, scientists hoped they would be magic bullets for a variety of diseases. Just inject them—and watch them race to injury sites and fill in for dying cells. In one early study, embryonic stem cells placed in the brains of rats suffering from symptoms of Parkinson's disease did precisely that. Not only did the cells become new neurons, but they began to squirt out dopamine, the chemical lost in Parkinson's. The problem was that they often ran amok, multiplying into frightening tumors called teratomas—disorganized mixtures of tissues, such as teeth, hair, and jawbone. Rats that developed such tumors died.

The brain tumors were a sign that the stem cells were still attempting to carry out their original mission: to form an entire person. Researchers quickly settled on a new strategy. They would use stem cells, but only to manufacture daughter cells restricted to a particular destiny—cells already committed to becoming liver,

turing them. But if proteins were harder to make than ordinary chemicals, cell therapy is an order of magnitude more difficult still. "Think about it," Cullen says, pointing through a glass porthole into the clean room, where the cells multiply in jars of pink medium. "The cell is a living thing—you can't define what it is with the same granularity." Indeed, the product that Geron makes can't be characterized like a chemical compound. Rather, it's a mixture of different types of cells, including oligodendrocytes. The manufacturing process is in many ways still undefined, Cullen says—still an art. When he heard that cells he'd cultured had been injected into someone's spine, "that brought it home," he reflects. "Now you know it's life and death."

RISKS VERSUS REWARDS

What worries some scientists is that Keirstead's results in rats have never been independently confirmed and published. That's not unusual in science, but it may be reason for caution in this case, since many discoveries in the stem-cell field have later unraveled. "I do think it matters if it is replicated," says Thomas Lane, a neuroscientist at the University of California, Irvine, who once

> What worries some scientists is that Keirstead's results in rats have never been independently confirmed and published. That's not unusual in science, but it may be reason for caution, since many discoveries in the stem-cell field have later unraveled.

say, or new muscle. "No one wants to put embryonic stem cells into humans, only the product," Keirstead explains today. What he worked out at his Irvine laboratory was a recipe for turning embryonic stem cells into relatively pure populations of oligodendrocyte precursors. It's not easy: his recipe requires 42 days of coaxing, coddling, and adding growth factors at just the right moment. Then, in 2005, Keirstead published a report saying that when he injected the oligodendrocyte cells into the spinal cords of crippled rats, they went from dragging their hind paws to walking again in a matter of days. That result was a bombshell, and Geron, which has poured $1.8 million into Keirstead's lab, quickly decided that pursuing a stem-cell treatment for people with spinal injuries would become the company's flagship program.

One of Geron's challenges has been to create an industrial recipe for growing the large numbers of cells needed for treating patients. The company's senior director for manufacturing operations, Sean Cullen, says Geron is now, with its technology, where companies such as Amgen and Genentech were with protein and antibody drugs a decade ago, when they began manufac-

collaborated with Keirstead to use the cells in mice with symptoms of multiple sclerosis, only to find that the cells didn't survive and did not appear to produce new myelin. While the two studies can't be compared head to head, says Lane, "at the end of the day [the cells] didn't work for us."

One complication in trying to reproduce the results is that other labs may begin with different populations of embryonic stem cells, and each lab has its own tricks for inducing the cells to differentiate, which makes direct comparisons difficult. Wenbin Deng, a professor at the University of California, Davis, has tried to replicate Keirstead's recipe, and the results leave him cautious about human tests. "I think it's still a little bit premature at this point," Deng says. "Even though this type of cell is ideal for transplant studies, there is still a lot of uncertainty about their safety and efficacy."

Geron scientists say they have replicated and extended Keirstead's findings, although the data haven't been published. "We would like to publish, but that is not the focus of the team," says Anna Krassowska, a stem-cell scientist who now works as Geron's director of investor relations. "Sometimes there is the perception

STEPHANIE DIANI

The Right Decision

By T. J. Atchison and Tory Minus

Before consenting to a medical procedure, a patient usually asks a key set of questions. What is the surgeon's success rate in performing the procedure? What are the risks involved? What are the typical post-op results?

Each of these questions weighed heavily on my mind the morning of October 4, 2010, the day I confronted the idea of becoming the first human candidate for embryonic-stem-cell therapy. Yet after reading over the 31 pages of a first-ever clinical protocol and investigator's brochure, I knew these questions could never be answered.

As I stared down at the pages, it was hard to grasp that just 10 days after being involved in a car accident—one that left me paralyzed from the chest down—I was now being faced with the biggest decision of my life.

I was a student at the University of South Alabama Nursing School, so I understood there were significant risks to being the first patient enrolled in any clinical trial. But nothing could prepare me for being the first person with a spinal-cord injury to be injected with more than two million cells grown in a laboratory from human embryonic stem cells. I kept thinking about a lecture on the promise of regenerative medicine I had attended only two weeks before the accident. It put in perspective what my participation could mean to millions of other disabled people.

After discussing the pros and cons of the procedure with my mother and maternal grandfather, I realized that I had a great responsibility to fulfill. I'd be the one to help doctors and researchers learn how these cells actually work in humans. I'd be able to encourage continued research in this controversial field from the perspective of someone who had been through the type of injury the researchers hope to treat.

Less than 30 minutes after being informed of the risks involved in the trial, I signed my name to the consent forms and initialed each page. Even under the pressure of the situation, I knew I was making the right decision. There were no false expectations about the infallibility of science, but I was doing this with the faith that I'd walk again one day. My faith carried me through it all.

Nearly eight months after being injected, I remain confident in my decision. However, I do admit that with each passing day, the fear of tumors developing at the injection site troubles me more. I find peace in the fact that even if this were to occur, I'd be helping researchers learn something about the procedure and what to avoid next time. Even if I became sick, I would still be contributing to the health of someone else, somewhere down the line.

T. J. Atchison is collaborating with Tory Minus, the editor of Alabama Living, *on a book about his experience.*

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that our entire trial is based on the seven rats of Hans Keirstead, and that is not true."

Yet even if the treatment heals rats, it is still unclear exactly what it does. Originally, the theory was that new oligodendrocytes should restore the missing myelin on axons, the projections of nerve cells that transmit electrical signals. But Ann Parr, a spinal surgeon and researcher at the University of Michigan, says the benefits appear so quickly—in a matter of days—that new myelin can't be the whole story. Maybe the cells emit chemicals that help prevent ongoing damage in some other way. "I think there is pretty good evidence that transplanting the cells can have a beneficial effect, but nobody knows how they work," says Parr.

For critics such as Caplan, the caveats add up to serious doubts. He says he doesn't see a reason for human tests given the "unimpressive" results in rodents, whose injuries were not as severe as those of Geron's human subjects. What's more, the patients Geron is treating aren't terminally ill. People who are paralyzed in accidents often adapt after the initial shock and return to relatively normal lives. "At first you think they don't have much to lose," Parr says, "but they actually do. They could die." None of those concerns weighed too heavily on Atchison, Geron's first patient. He signed the forms to join the trial only 30 minutes after reading them. Since the injection, Atchison has worried more about the prospect of developing a tumor, but he has come to terms with the danger. "Even if I became sick," he says, "I would still be contributing to the health of someone else, somewhere down the line" (see *"The Right Decision," left*).

The job of balancing the evidence for and against stem-cell therapy fell to the U.S. Food and Drug Administration in 2008, when Geron first submitted its application to test the treatment in people. For the agency, which is charged with ensuring the safety of all medicines, embryonic stem cells were not only a charged political subject but a huge technical challenge. When the FDA called together its top advisors that year, at the Hilton Hotel in Gaithersburg, Maryland, to discuss whether to approve Geron's treatment, one participant called stem cells "probably the most complex biological therapeutic humanly imaginable."

Everyone was well aware of how some previous attempts to alter the body's cellular and genetic makeup had gone wrong. In addition to the infamous gene-therapy death, there was the case of Parkinson's patients who began to experience uncontrolled movements after receiving transplants of tissue from fetuses. Also worrying was a French study a decade ago in which transplants of genetically altered bone marrow had cured children of severe combined immunodeficiency, or "bubble boy" disease, only to cause leukemia years later. Unlike ordinary drugs, whose action quickly fades, these treatments threatened to get stronger. "For some products," agency officials noted, "unchecked proliferation is a real possibility."

LOOKING AHEAD Atchison, shown here at his home in Chatom, Alabama, says he sometimes worries about the dangers of Geron's new treatment but has faith that his participation in the clinical trial will help others.

The FDA's overriding worry was that a stray embryonic stem cell could cause a tumor. After the 2008 meeting, the agency told Geron that its trial couldn't proceed. The problem: some of Geron's rats had developed tiny cysts where the treatment had been injected. Jane Lebkowski, Geron's chief scientific officer, says the growths were harmless masses of epithelial cells, like "microscopic water balloons." Harmless, maybe. But they didn't belong in the spinal cord, and who knows how much they might grow during a human lifetime. Lebkowski says Geron adjusted its manufacturing recipe to eliminate the unwanted tissue. But it took the company another two years—and a hundred or so more rats—to persuade the FDA that its product was safe enough to test in people. Even so, the FDA demanded unusual safety precautions—stipulating, for example, that the patients be tracked for years to come.

Such delays add up, and some believe the FDA is creating a road-block. Several companies have gained the agency's approval to test injections of stem cells taken from immature human fetuses, an older but related technology that has also raised concerns at the FDA. "The problem is that the agency is overworked and understaffed and isn't so familiar with cell therapy," says Richard Garr, CEO of NeuralStem, a company that recently began tests of fetal spinal-cord cells in patients with Lou Gehrig's disease, or ALS. For NeuralStem's study, like Geron's, the agency required that patients be treated at least 30 days apart, to allow time to tell whether problems would arise. It will take the company at least a year and a half to complete the study, given that 18 patients are expected to enroll. "And here is a disease that kills you in three to five years, on average, after diagnosis," says Garr. "So it feels like they are slowing you down. I think the FDA believes the caution is justified. I can tell you that the patient advocacy groups are frustrated."

Indeed, many patients opt not to wait. Unregulated clinics, cranks, con men, and quacks have popped up from Cancún to Beijing, tempting patients to pay as much as $40,000 for the chance of a stem-cell miracle. But medical tourists who dodge U.S. safety regulations for overseas injections run unknown risks. In 2009, Israeli doctors treating a 13-year-old boy reported the first case of a brain tumor caused by a stem-cell therapy. The boy's parents had taken him to a fly-by-night Moscow clinic where cells gathered from human fetuses had been injected into his brain.

Patients who join the Geron study, by contrast, will be subject to a battery of MRIs, blood tests, medical exams, and follow-ups lasting 15 years. Perhaps because of the demands put on candidates, the trial has been moving at a crawl. In April, the company surprised investors when it reported that in six months it had managed to enroll only one patient. The good news was that the patient, Atchison, had suffered no unexpected side effects. The bad news, even after the second patient was enrolled in May, is that at this pace it will take Geron an agonizing three years to finish. CEO David Greenwood says that the company has asked the FDA to loosen the strict criteria for subjects. "Cell therapies are new, and the agency appropriately, I think, takes a very conservative posture," he says. But, he adds, "you can narrow your funnel so much you don't get any patients."

Back at his office at UC Irvine, Keirstead says he has received several phone calls from people who were considering joining the Geron trial: "They were looking for a level of confidence, a feeling from me. Is it really going to work, and is it safe?" The calls have put Keirstead in a difficult spot. "My ridiculous sense of optimism may be clouding my judgment," he says. "But I tell them we've done everything we can possibly do scientifically and in animals. And we still don't know if it works in humans." **tr**

BRIEFING
Social Networks

TANGLED WEB Facebook CEO Mark Zuckerberg addresses developers creating applications that integrate with his social network.

Can online communities manage their privacy problem?

Social networks are redefining the way people find and share information, they've provided a platform for a new wave of applications, and their impact has even spilled over into this year's revolutions in the Middle East. The operators of these networks make money primarily through ads, wooing advertisers with the prospect of campaigns better targeted than anything competitors like search engines or television can provide.

Consequently, social networks present the first serious challenge to the dominance of Google's search-based advertising business.

But to provide precisely targeted advertising, they must continue to make the most of the personal information provided by users. In the past, network operators have had a largely free hand in how they used that information, but on a number of occasions they provoked howls of protest by overstepping the mark. Now privacy concerns are becoming the focus of attention from consumer advocates and governments around the world (see "When Private Information Isn't," p. 63).

These concerns will become even more pressing as social networking is integrated with more and more online services, such as personalized search tools that factor in what you and friends like or recommendation engines that suggest which movies to see, restaurants to visit, or news to read. But even as privacy issues linger, it's likely that before long, not having a profile and some connections on at least on one social network will seem as strange as not having an e-mail address or a cell phone. —*Stephen Cass*

BLOOMBERG VIA GETTY IMAGES

TECHNOLOGY OVERVIEW

Managing Users by the Million

At the heart of social networks are their enormous repositories of data: personal details and messages, huge quantities of photos and videos, and the complex web of connections that reflect the actual social relationships among users. Successful networks are those that have mastered how to store, secure, and quickly access and analyze this data.

The numbers are staggering. By late last year, Twitter's users were generating 12 terabytes a day, which adds up to four petabytes a year, or the equivalent of 83,000 Blu-ray video disks—and that's assuming no further user growth.

The networks rely partly on hardware to deal with this flood of data, building large data centers stuffed with servers. The other part of the solution is the software: many companies are contributing to open-source code designed to handle big databases. Twitter uses an open-source database called Cassandra that's designed to work at large scales, with processing tasks distributed across a variety of relatively cheap servers.

In addition to storing data, keeping up with users is a challenge, even when they do something as apparently simple as clicking a "Like" button. Every time a user

reports having watched a television program, for example, there's already been "a lot of calculation to support that," explains Alex Iskold, founder and CEO of Adaptive Blue, the company that maintains the entertainment-oriented social network GetGlue *(see "Turn On, Check In," p. 64).* Each such note causes a cascade of calculations about what other media content to recommend, what information to display to other users, and whether any promotional incentives should be offered to the user. "The hardest thing to deal with is

DATA POINT

107.4 million

Predicted number of Europeans
who will be regular users of social-
networking sites by the end of 2012, up
from 41.7 million in 2008.

JASON MADARA

POPULATION EXPLOSION

The number (in millions) of Facebook users has skyrocketed since the network was founded in February 2004.

600
500
400
300
200
100
0

Feb '04   June '11
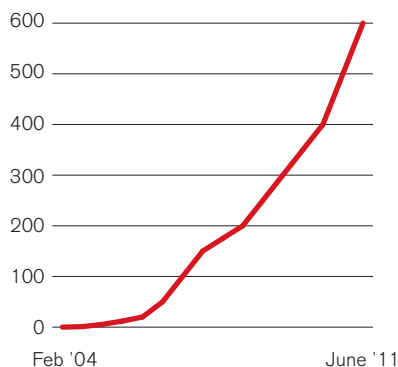
Source: Facebook

bursts," Iskold says, referring to the surges in traffic during big events like the Oscars.

The information that social networks provide about users' connections and interests has, despite initial doubts about its commercial value, proved incredibly lucrative. Social networks typically analyze the personal information provided by users to offer advertisers closely targeted commercial placement, a business that's worth billions of dollars per year and growing. The value lies in "the combination of technology and identity," says Jascha Kaykas-Wolff, senior vice president of marketing and customer success for Involver, a company that builds technology to help its customers create social-marketing campaigns. Data analysis tools are also being used to improve search results *(see "Personalized Search," p. 65)*.

The value of these networks attracts scammers as well as advertisers. In 2011, the security company Sophos reported that 40 percent of those who use social-network sites have received malware, 43 percent have been subjected to phishing attacks, and 67 percent have received spam. In response, network operators have begun watching for patterns that indicate mali-

cious activity (for example, a link being shared among users faster than a human could reasonably accomplish it) and trying to develop technology to block these attacks before they reach users. The social-gaming network Zynga tracks sites that host hacks, bots, and cheats and monitors users sus-

pected of bad behavior. Facebook has also recently introduced the option of texting a pass code to a user's phone when that person's account is accessed from a new computer, in hopes of preventing unauthorized access to an account if a password is compromised. —*Erica Naone*

INDUSTRY CHALLENGES

When Private Information Isn't

Personal information is the fuel that powers Facebook, Twitter, Myspace, and the other social networks, attracting users and advertisers alike. But privacy activists and regulators are taking a close look at the way all that information is collected, used, and protected, and this scrutiny could result in strict rules for network operators.

These watchdogs are finding that operators have repeatedly left personal information and subscriber data vulnerable, leading to highly visible privacy snafus that exposed users to the risk of embarrassment, identity theft, or even stalking. In February of

last year, for example, Google launched its social-networking service Buzz with default settings that revealed whom users were e-mailing frequently. (Google was forced to make a settlement with the U.S. Federal Trade Commission, requiring it to submit to independent privacy audits for the next 20 years.) Then, in June, a hacker exploited a bug to capture the names and profile photos of approximately 70 percent of Foursquare users in the San Francisco area over a three-week period, regardless of privacy settings. Similar problems and allegations have plagued other social-media websites.

PERSONAL QUESTIONS In May, executives from companies including Google and Facebook testified at a U.S. Senate hearing on privacy.

State and federal legislation has been proposed to address these issues. A bill in Congress would greatly expand the FTC's ability to regulate online privacy, defining e-mail addresses and precise geographical locations as personally identifiable information that must be adequately protected and compelling companies to get permission before they can collect medical and religious data.

Complying with these regulations could require social networks to make costly changes to their infrastructure. In addition, operators would be exposed to greater legal risk if they were caught collecting restricted data, whether accidentally or otherwise.

PRIVACY CONCERNS
Social-network users were asked in 2010 how worried they were about violations of their privacy.

- 21% Not concerned at all
- 23% Very concerned
- 29% Not very concerned
- 27% Concerned
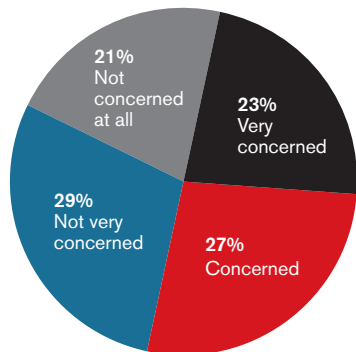
Source: The Marist Poll

Not surprisingly, many social-network operators claim that they are complying with existing law and that more regulation is unwarranted, even counterproductive. They contend, for example, that users who face a slew of detailed questions about how they want access to their information controlled before they even start using a service may become confused and make poor privacy choices. Nevertheless, it seems likely that the freewheeling approach of the industry's early days will be curtailed in some fashion before too long.
—*Simson L. Garfinkel*

CASE STUDY
Turn On, Check In

GetGlue is a social network for fans of TV programs, music albums, and other entertainment. People watching a show or listening to an album can "check in" to it on GetGlue the way users of Foursquare might record their presence in a coffee shop. GetGlue can use those check-ins, and the check-ins of friends, to recommend other content. Users can also get rewards such as souvenir stickers. Run by the New York–based startup Adaptive Blue, GetGlue was launched in 2009 and recently passed one million users, recording 55 percent more check-ins in April than in March.

According to Adaptive Blue founder Alex Iskold, the turning point was the release of GetGlue's iPhone app last summer; currently, 70 percent of check-ins come from mobile devices. GetGlue also has partnerships with 35 cable and broadcast television networks and 10 movie studios, including Fox, Disney, and Sony Pictures. Some of these partners pay GetGlue, but most simply provide promotional services such as on-air mentions and tweets about GetGlue by media producers. In return, GetGlue organizes sticker campaigns and online groups that encourage fans to watch or listen.

In addition to setting up paid partnerships, Iskold plans to sell space to advertisers already pursuing the audience of a TV show. Marie-Jose Montpetit, a researcher at MIT who studies social television, says GetGlue is attractive to networks because digital video recorders and on-demand streaming services are threatening to divert the live viewers who are a captive audience for on-air advertisements. Social involvement makes the initial broadcast of a show feel more like an event that can't be missed.

Iskold believes he has found a niche that doesn't require him to compete directly with the likes of Facebook. And while startups such as IntoNow, Miso, and Tunerfish also promote social networking around television, Iskold says GetGlue stands out because users get rewards that come directly from their favorite media creators. Ultimately, GetGlue's true competition might turn out to be companies such as Nielsen, which have traditionally provided information about consumers' viewing behavior. —*Erica Naone*

DATA POINT

$7 billion
Estimated revenue generated from selling virtual goods to users of online games and social networks in 2010.

Anonymous Tracking

When online services are accessed via a Web browser, geolocation technology can pinpoint the user's position to within a few meters, employing a combination of the user's IP address, the route taken by packets over the Internet, and any Wi-Fi networks that might be in range of the user's computer. It's even easier if a cell-phone app is used; the app can read the phone's GPS and know, for example, every time the user walks in front of a Starbucks.

So why aren't we already in an age of geospatial advertising, where companies like Facebook and Google send coupons to users' phones as they pass by advertisers'

LITTLE BROTHER Mobile-device users are often happy to volunteer their location to services like Foursquare but balk at unrestricted tracking.

stores? One big problem is the difficulty of serving up such ads without compromising users' privacy.

One possible solution is anonymization, scrubbing identifiers from personal data records so that advertisers get the absolute minimum of information they need—a

MOBILE ACCESS

The number of smart phones (in millions) continues to grow, and they are increasingly used to access social networks.
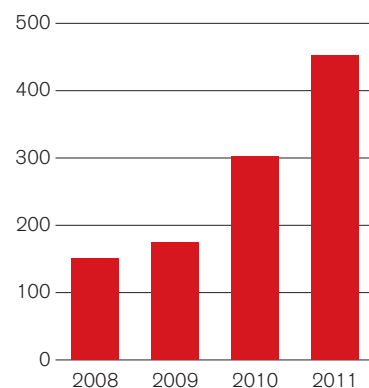
Source: IDC

trendy clothes retailer might care that a user is a woman aged 18 to 34, but it doesn't need to know which 18-to-34-year-old woman she is. Or it might care that a user is near one of its stores without caring which store. Anonymization would let phones communicate with advertisers, providing location and general demographic information without revealing the user's identity. However, it's proved surprisingly easy to reassociate scrubbed records with specific individuals.

In response, researchers are developing new mathematical approaches to protecting identity. Efforts are under way at Microsoft to ensure that an individual's contribution to, say, a demographic database cannot be isolated. Researchers at IBM are working on an encryption method that, in five to 10 years, could allow information to be analyzed without ever

being decrypted *(see "TR10: Homomorphic Encryption," May/June 2011)*. That means companies could search for users whose location matches that of a store without ever getting access to personal details.
—*Simson L. Garfinkel*

Personalized Search

Google's original breakthrough in search technology was to assess the value of a Web page according to how many other pages linked to it—an indirect measurement of how many people liked that page. Social networking offers another way to measure how many people think a page is worth looking at: examining which links users share with their friends.

While the pool of pages ranked through social networking will never be as comprehensive as that produced by Google, it has the advantage that it allows for more personalized search results. A person whose circle of friends shares a lot of sports-related content is more likely to be looking for information related to the Texas basketball team when searching for "Rockets" than someone whose friends like a lot of space-related topics.

With its hundreds of millions of users and its "Like" button, which lets users note which pages they like even while visiting other websites, Facebook is the leader in this new approach to indexing Web content *(see "TR10: Social Indexing," May/June 2011)*. In May, Microsoft started using data from Facebook to weight results from its search engine, Bing. Not to be left behind, Google recently added a "+1" button that allows users with public Google profiles to note pages that interest them and draws on this information to recommend pages to other users. —*Stephen Cass*

MOLDOVA

TURKMENISTAN

UZBEKISTAN

SYRIA

TUNISIA

IRAN

LIBYA

CHINA

NORTH
KOREA

SAUDI
ARABIA

EGYPT

BAHRAIN

BURMA

VIETNAM

CUBA

■ Countries in which
social networking has
played a significant role in
antigovernment protests
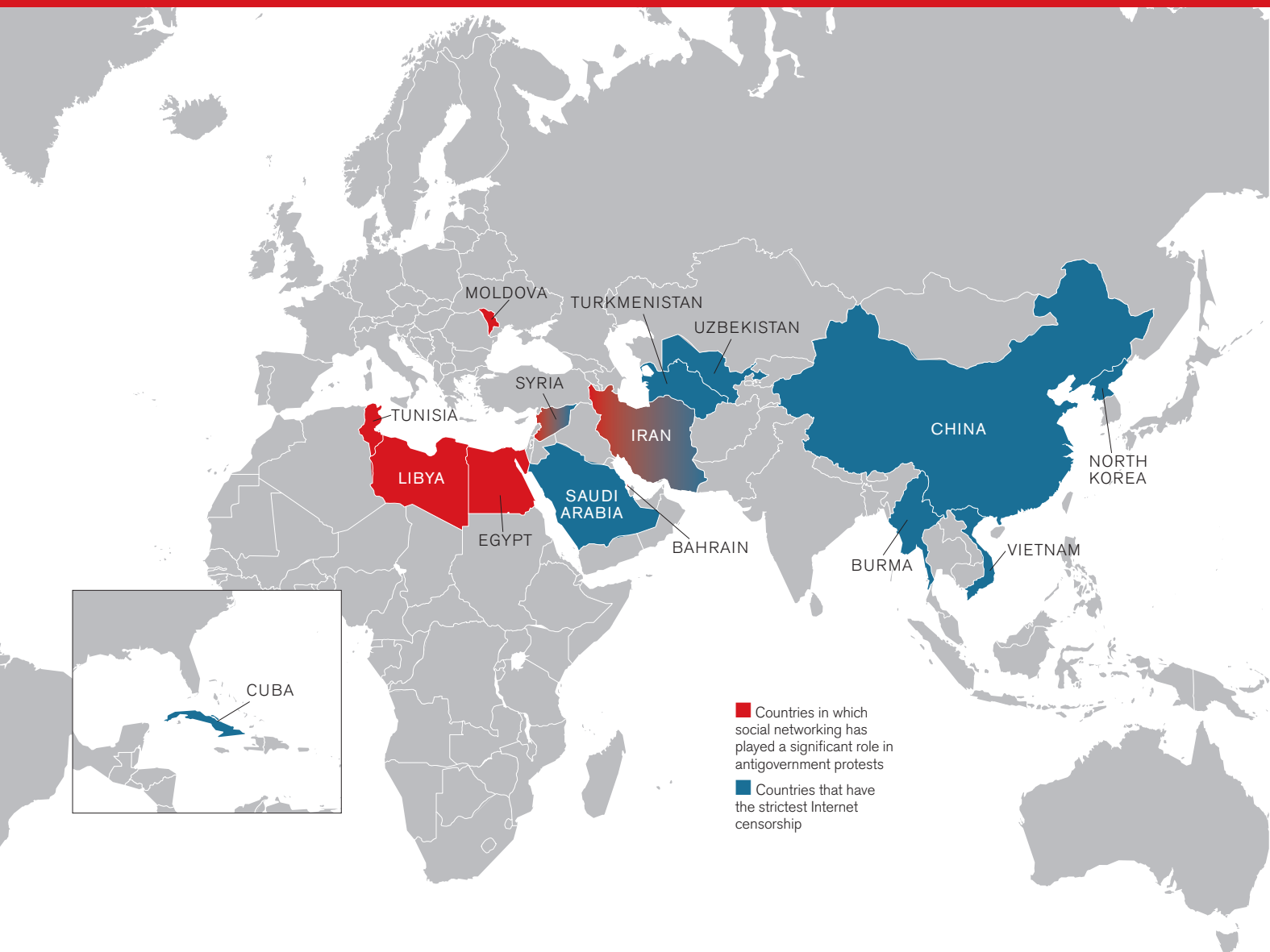
■ Countries that have
the strictest Internet
censorship

From Online to On the Streets

Clearly, authoritarian regimes feel they have something to fear from social networks. Internet censorship has become almost synonymous with blocking open access to sites like Twitter and Facebook; regimes either shut off access during periods of social unrest or ban certain services permanently. Reporters Without Borders, a nonprofit that advocates for international press freedom, maintains a list of the most censorship-prone nations, indicated here in blue. Some of these countries, such as Syria and Iran, have already experienced protests in which social networks have played a role, while others, such as Cuba, appear to be limiting access on general principles.

Nonetheless, in many cases protesters have been able to bypass censorship. That's happened in Egypt and Tunisia, two countries Reporters Without Borders had previously listed as among the most restrictive.

Would the popular revolutions occurring throughout the Middle East have happened without social-networking websites? Researchers will probably be debating that question for years, but there is no doubt the social networks have proved vital to organizing mass protests and to documenting the often brutal tactics of repressive regimes, thereby galvanizing both local and global support for the revolutionaries' cause. —*Stephen Cass*

RINGING THE BELL Investors are eager to buy in to companies like LinkedIn (whose executives recently opened the New York Stock Exchange), raising fears of a new dot-com bubble.

MARKET WATCH

Advertisers Flock to Social Networks

With Facebook leading the pack, social networking is aiming to catch up to the $25 billion worldwide business in search ads. Facebook has more than 600 million active users who log on at least once a month, constituting a market so appealing to advertisers that the company's value is estimated to be a breathtaking $50 billion to $65 billion.

Marketers worldwide will spend nearly $6 billion advertising on social-networking sites this year, up 72 percent from 2010, the business information service eMarketer predicts. Facebook alone is expected to account for over $4 billion of that, more than doubling last year's revenues and helping to boost global ad revenues for social networks to nearly 9 percent of online ad sales.

Still, Facebook will face increasing competition for social-network ad dollars. The business-oriented LinkedIn has more than 100 million users, and Twitter has 200 million (though it's not publicly known just how many people use either site regularly). And heavyweights in related industries are

taking an interest: Google CEO Larry Page, stung by the company's failures in social media, has reshuffled senior management to make infusing social connections into search and other services a top priority.

MARKET EXPANSION

Social networks' global ad revenue (in billions of dollars) is predicted to rise rapidly.

- ■ Facebook
- ■ Myspace
- ■ Twitter
- ■ Others

Source: eMarketer

Apple has launched Ping, a social network tied to the iTunes music store.

Competition remains wide open in several international markets. Mixi, Gree, and Mobage-town are battling for dominance in Japan, Cyworld and me2DAY are popular in South Korea, and Vkontakte.ru leads in Russia. China, where access to Facebook is currently blocked, has entrenched local networks such as Renren, which boasts 31 million users and raised $743 million in its U.S. initial stock offering on May 4.

Of concern to all social networks is slowing growth in the user base. After a 19 percent jump in the number of U.S. users last year, eMarketer predicts just 4 percent growth in 2013. So it will be crucial to reap more advertising and e-commerce dollars per user through targeted campaigns *(see "You Are the Ad," May/June 2011).*

Social networks are also working to expand their revenue streams beyond advertising. LinkedIn and Ning charge subscription fees for various services. Facebook, through its Credits payment system, takes a 30 percent commission on sales of everything from movie rentals to virtual goods purchased in Facebook-based applications such as Zynga's FarmVille game. Web services like Groupon and Living Social (and now Facebook) offer users coupons from local businesses, taking a cut of any business that gets drummed up. —*Robert D. Hof*

DATA POINT

$94.25

Closing price of LinkedIn's shares—resulting in a value of nearly $9 billion—on May 19, the day the company made an initial public offering opening at $45 per share. The company does not expect to be profitable in 2011.

THE BIG PICTURE

Social Machinery

Asingle page on a social-networking website is an amalgam of many different technologies. Each user is served a unique page assembled from up-to-the-second information from multiple sources. During assembly, attention must be paid to each user's personal preferences, the privacy settings of the user's friends (and friends of friends), and the advertisements that seem most likely to find a favorable reception *(see "Managing Users by the Million," p. 62)*. Here we show some of the hardware and software required to support key elements of a typical page belonging to one of Facebook's 600 million active users.

The hardware depicted is largely located in the company's new 31,000-square-meter data center in Prineville, Oregon. This facility uses evaporative cooling to control temperatures. Facebook claims that the cooling technology, together with a new electricity distribution system, has made the data center 38 percent more energy efficient than a traditional center, with operating costs about 24 percent lower.

Facebook has made the designs for the Prineville data center, and the customized servers within it, available to anyone—a decision that reflects in the physical sphere the social network's heavy use of open-source projects in its software. —*Stephen Cass*

OTHER DATA CENTERS
Several data centers share information directly with one another, allowing for load balancing and rapid synchronization of user data.

PHOTOGRAPHS
The more than 100 million photos uploaded daily are stored in a distributed database called Haystack, developed by Facebook.

CONTENT DELIVERY NETWORK
Commercial services store and distribute pages to users so that data centers don't become bottlenecked.

FACEBOOK PAGE
Each Web page is assembled from data drawn from different systems within the data center. These include systems responsible for photographs (blue), the news feed (green), the "Like" button (purple), third-party applications such as games (pink), and advertisements (yellow).

USER INFORMATION
Text-based data about users, such as personal information and the identities of their friends, is stored on servers running MySQL, an open-source database.

ELECTRICAL SUBSTATION
The electrical system distributes 277 volts to servers rather than the 208 or 120 volts typical for data centers. Conversion losses from the utility connection to the server are only 2 percent, rather than the typical 11 to 17 percent.

SECURITY
Connections from third-party sites are analyzed to guard against malware.

TRACKING LOGS
Open-source Hadoop database software is used to monitor user activity.

THIRD-PARTY PROVIDERS
Data feeds come from external sources, such as Zynga, which operates the popular FarmVille game.

FACEBOOK PLATFORM
Servers provide an interface for external developers to use in creating apps that can be integrated into Facebook pages or websites that work with the social network.

"LIKE" BUTTON
These servers track how users on Facebook—and a growing number of external sites—are using the "Like" button to signify interest in Web pages.

NEWS FEED
This is where posts from other users and notifications from applications are filtered and assembled into a chronological list.

RACK SERVER
Prineville's servers use a new design with a high-efficiency power supply. It can accept either 277 volts of AC power or backup DC power from battery cabinets that can each supply multiple servers.

WEB SERVERS AND CACHES
Data from the other servers in the center is assembled and formatted into the HTML that makes up a Web page in servers (orange) running PHP, an open-source scripting language. Frequently accessed content is cached in intermingled servers (blue) for rapid retrieval without overloading the internal infrastructure of the data center.
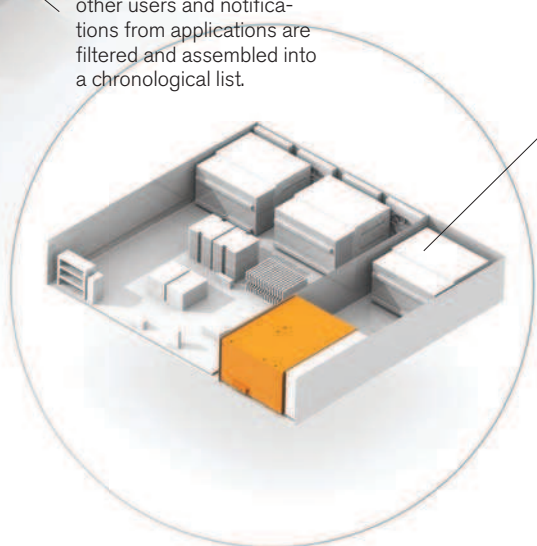
FOOD

Better Cooking through Technology

The former CTO of Microsoft has created a gigantic guide to kitchen science that could transform the way we eat.

By CORBY KUMMER

To see *Modernist Cuisine* is to covet it. Which is why, one morning in May, the team that spent six years creating the oversized, over-everything five-volume work came from Bellevue, Washington, to New York City to introduce the wondrous object. And it is why a group of chefs, writers, and TV personalities (so stellar that one guest remarked, "The only other event that could bring these people together is a funeral") gathered at Jean-Georges, the flagship restaurant of Jean-Georges Vongerichten, at the invitation of Tim and Nina Zagat. They were there to meet Nathan Myhrvold, the mastermind and financier of a book so expensive to create that he refuses to say how much he spent (other than to say it was more than $1 million but less than $10 million). They wanted to try the pastrami cooked sous-vide for 72 hours, the "tater tots" dunked in liquid nitrogen before being fried, the fruit juices spun in a centrifuge, the mushroom omelet striped with powdered-mushroom batter so that it looked like a piece of upholstery, with a perfectly spherical, magically just-cooked

Modernist Cuisine
by Nathan Myhrvold, Chris Young, and Maxime Bilet
2,438 pages; $478
The Cooking Lab;
Spi Har/Pa edition
2011
modernistcuisine.com

egg yolk right in the middle. But they really wanted to see the book.

And it *is* a wondrous object. *Modernist Cuisine*'s five volumes comprise 1,522 recipes and 1,150,000 words of text on 2,438 pages, almost every one of them illustrated with color photography and charts, with dozens of gee-whiz, never-before-seen photographs of beautiful free-form color swirls that could be textile designs but turn out to be life-threatening pathogens; or sculptural objects that could be outdoor art installations but are mussels suspended in clear gelatin; or stunning anatomies of a painstakingly shelled lobster or flayed monkfish or whole chicken; or spectacular cross-section cutaways of pieces of equipment you never thought would or should be sawed in half, like ovens, woks full of hot oil, and kettle grills with white-hot smoldering coals. It weighs 40 pounds, four of them just ink. When Wayt Gibbs, the book's editor in chief, met me later that week in Cambridge, Massachusetts, at Toscanini's, an ice-cream parlor and intellectual salon heavy with MIT students and faculty, he

painstakingly unwrapped the gigantic carton he had lugged on a portable dolly from Bellevue to New York and then to Boston. The café-goers grew silent and stared at the huge white volumes in their clear Lucite case, one of them later wrote me, as if they were the monolith in *2001*.

The long-awaited publication of *Modernist Cuisine*, in March, was the most significant event in the food world since ... well, there might not be a precedent. The 6,000 copies that Myhrvold printed privately—against more conservative advice from what he describes as "cooler heads" in book publishing—immediately sold out at the introductory price of $465. "We sold 9,000 of those 6,000 copies," Myhrvold says with satisfaction. He quickly ordered 25,000 more copies to be printed.

To research the book, Myhrvold built a 4,000-square-foot laboratory, kitchen, and photo studio in an 18,000-square-foot former motorcycle showroom in Bellevue, where an ever-expanding team of cooks experimented with machinery usually restricted to doctor's offices, hospitals, and commercial food processing, using powders and essences and chemicals similarly typical of the food industry.

Such experimentation had been going on for years, of course, most famously starting in the early 1990s at Ferran Adrià's El Bulli in Catalonia, Spain, and in the mid-1990s at Heston Blumenthal's Fat Duck in Berkshire, England—the two main inspirations for Myhrvold and his team, whose lead members trained with Blumenthal. In this country, it was hard for ambitious young chefs to visit a similar nucleus of cooking research unless

LONG WARM BATH One new kitchen tool is the water circulator for sous-vide cooking. Food sealed in bags cooks at controlled temperatures for as long as several days.

they could get into Grant Achatz's Alinea, in Chicago (*see "The Alchemist," January/ February 2007*). Or unless they were among the favored few to be invited to one of the 30-course tasting dinners in the Bellevue lab, which were reserved mostly for cooks and industry leaders who had lent expertise or machines to the team, and for reporters like me who wanted a look at just what went into the three years of decision making, recipe testing, writing, and editing that preceded publication.

Myhrvold himself is an object of intense interest. The former chief technology officer of Microsoft and the founder of the patent investment company Intellectual Ventures, he is a genius and billionaire who still indulges his boyish enthusiasms, which include photography and dinosaurs but revolve mostly around cooking. The interest began at age nine, when he nearly set his mother's kitchen on fire in a plan to flambé everything for a Thanksgiving dinner. Myhrvold is a charming, even twinkling, spokesman for his mad-inventor processes—quite unlike, say, Ferran Adrià, whose trademark is a messianic intensity and utter imperviousness to anyone not as focused as he on the windstorm of creativity ever blowing round his brain. Myhrvold's voice is strong enough to come through in many sections of the book, though they're unsigned: a droll account in the third volume of traveling to Greenland and eating rotten shark, which "doesn't taste like chicken," is probably his. So is much of an excellent chapter in the fourth volume on coffee, in which he goes in search of what baristas call the "God shot" and in the process learns and shares a terrific amount of information on roasting, grinding, foaming milk, and pulling espresso shots.

JUSTIFIABLE COST

I managed to get my hands on the copy Gibbs unpacked at Toscanini's. Opening any volume brings you right to cutting-edge techniques that produce food unlike anything anyone has ever tasted outside El Bulli or the Fat Duck or Alinea.

40 POUNDS OF TEXT Even with his eye on the future, Myhrvold insists that the printed page still offers the best way to absorb this much information.

But the high-tech toys and futuristic food are not why I think you should put yourself on the wait list and spend the $478 the book now costs (unless you want to spend the $800 and up being asked for "used" copies). Although some of the futuristic food is fabulous, as I learned from the 30 courses I got to try at the lab, the reason to pony up the going rate is that *Modernist Cuisine* is an incomparable introduction to many of the basic techniques of food and cooking. Within its five volumes (six, actually, including a spiral-bound book of recipes for the professional kitchen) are several long chapters that are as comprehensive and readable and valuable as any books I've seen on subjects essential for anyone interested in food.

The first volume alone contains a long, definitive introduction to food pathogens and food safety, a subject cooks ignore at their peril. The other volumes give basic information on science, ingredients, and techniques common to all cooking, not only "modernist" cuisine. And, of course, the book is a guide to the avant-garde—one far more comprehensive and usable than anything else yet written. As for the food, there are those 1,522 recipes, and if you can lay out a fairly substantial sum and clear enough

counter space to start trying them—well, more on that later.

I didn't read all 1,150,000 words—no one other than Gibbs has claimed to, he told me when I spent a few days in the Bellevue kitchen. (He also admits to having tried only a few recipes, because he's not a cook.) But I'll claim a good 750,000. Watching the media appearances of the buoyant and unfailingly enthusiastic Myhrvold; visiting the book's website for cool videos of machines and pots being sawed in half or a kernel of popcorn dancing across a black screen until it explodes and soars up and off like a rocket; even eating 30 courses in Bellevue—none of it prepares you for the experience of reading *Modernist Cuisine*.

Everything about the book has been designed to keep a reader going, with bits of information in the margins and pages-long interruptions for techniques, cooking charts, and "parametric" and "example" recipes. Some sidebars go on for a few pages; they're printed in white type against black, as are most of the charts, so that the flow of text, though unusually complex, becomes intuitive. As in a magazine or textbook, captions provide complementary information and précis that make you feel you've got the gist of the main text.

The similarity to magazines and textbooks is not accidental. Myhrvold and Chris Young, a scientist and former Fat Duck chef who is listed as an author along with Maxime Bilet, another Fat Duck alumnus and the head chef of the Bellevue kitchen, were influenced by the illustrated Time-Life series of cookbooks from the late 1970s and early 1980s—books, like this one, assembled by veterans of the magazine and book worlds who knew how to unite text and photographs for maximal informative value. Gibbs, who's been a writer and editor at *Scientific American* and has extensive experience creating illustrated features, served as producer for a total of 44 writers, photographers, designers, researchers, and editors whose combined efforts bring life and interest to every page.

Myhrvold has been derided for producing a book, that most old-fashioned of objects, rather than a $5 app. His reply: a "really good" electronic version, with interactive features to recipes, animations for key techniques, and video clips, would be a project "bigger than the one to do this book." A book is still the best way to publish so much information, and the spiral-bound supplement, unlike an iPad, is waterproof. And with a few exceptions (such as much of Volume 4, which is devoted chiefly to thickeners, gels, emulsions, and foams—the trickiest of the new chef's tricks), my interest never flagged.

Visiting the book's website for cool videos of machines and pots being sawed in half or a kernel of popcorn dancing across a black screen until it explodes and soars up and off like a rocket; even eating 30 courses in Bellevue— none of it prepares you for the experience of reading *Modernist Cuisine*.

COOL TOOLS

The book I'd make required reading for any cooking student is Volume 2, on techniques and equipment, which gives as good a description as I've seen of basic processes like baking and frying. This is also the volume that lists the toys in the toy box. Number one on the list is a sous-vide water bath—a tool that is ubiquitous in the recipes, particularly for meat. The bulk of the volume, unsurprisingly given the project's origins as an eGullet chat forum Myhrvold opened about sous-vide, is devoted to this technique, which Myhrvold and many other cooks value for its precise control and predictability. Thanks to the enthusiasm of chefs like Achatz, Thomas Keller (who wrote a book on the method), and Philip Preston, of

PolyScience, a manufacturer of controlled-temperature equipment who worked closely with Achatz and Myhrvold, the water bath has gone from science-lab "immersion circulator" to almost-affordable kitchen tool.

I don't have the patience for sous-vide, and I find that it produces too soft a texture in meat and fish. The piece of equipment I'd like to buy is a combination dry- and steam-heat "combi" oven, which so far hasn't found a manufacturer like Preston willing to work on one for the Williams-Sonoma crowd. There are tiny ones for $2,000, but they hold almost nothing; models not much bigger than a big microwave easily cost $12,000, and the authors say you need a couple of those. Still, the fact that the ovens thaw, steam, poach, and roast makes them as appealing to me as the microwave— which, hearteningly, the authors endorse for cooking vegetables, frying tender herbs, and turning vegetable juices into "perfect powders."

The authors do list cool tools that are within the reach of many home cooks, like digital scales and thermometers; the carbonator, for foam; a Toddy cold-brewing coffee kit, for deriving extracts of many flavorings besides coffee; and my favorite all-purpose tool, a pressure cooker, something I use nearly every night. The reason that stocks made in pressure cookers are perfectly clear, they point out, is that the water inside never boils, and the motion of boiling is what emulsifies oil and creates scum in normal stocks. They give everyday tips for ways to use the device, including making risotto (a longtime guilty secret of time-pressed Italian cooks, who will reveal it only after receiving compliments on how good their risotto is) and adding calcium chloride to the water for beans to let them soften without splitting their skins.

The tool many professional chefs may decide they need is a centrifuge, which costs $10,000 to $30,000 and can take up as much room as a washing machine. Myhrvold's team used a centrifuge to clarify juices from citrus and from sous-vide bananas, which became

translucent and serum-like. Thomas Keller, chef of the French Laundry in Yountville, California, decided he needed a centrifuge after he saw the Bellevue lab use one to separate the fatty solids from peas to make "pea butter," spreadably thick and perfectly smooth.

And some chefs might sign on to the tank of liquid nitrogen that the team says is second in utility only to the sous-vide water bath. Dunking a food in liquid nitro before you fry it—"cryofrying," the lab calls it—makes the outside of, say, cubed pork or sous-vide chicken or "tater tots" hot and crisp while the interior turns out just warm and not overcooked. It also makes soft foods manageable to slice thin or to grind. Cubes of beef can be put into meat grinders, drawn out in parallel, extruded strands, and carefully rolled into plastic-wrapped cylinders. After being submerged in liquid nitro, they're cut into patties and deep-fried for hamburgers that, as Jean-Georges Vongerichten reported with wonder, are juicy and crumbly without being fatty or tough. But the grown-up boy magicians on the *Modernist* team use the cooling agent, they admit, "for just

about every food," because it's "just plain fun"—for instance, to "cryoshatter" olive oil for a garnish.

POSSIBILITIES

Volume 3, on animals and plants, is both an anatomy class and a guide to how proteins and fibrous plants react to heat. The section on meat includes wonderful color diagrams of muscle fibers and collagen that do more

than anything else I've ever seen to explain the structure of meat and make it clear why different cuts cook differently. The section on vegetables is a good bit shorter, perhaps reflecting the cooks' degree of interest. (They seem to have been intensely interested in the heat scale of peppers, though.)

Volume 4, on ingredients and preparations, spends the most time on thickeners, this being "truly the best age ever in which to thicken a liquid." I was glad to learn about viscosity and fluid gels, and to discover that alginate, a hydrocolloid extracted from brown seaweed, is the key to the "spherification" that Adrià has made almost as popular and widespread as foams. But for anyone who doesn't plan to buy Ultra-Sperse 3 or Ultra-Tex, or N-Zorbit M or even xanthan gum—all of which are turning up in modernist-inspired kitchens, and all of which appear in dozens and dozens of recipes in the book—this will make the least absorbing reading.

I'd argue that the plated-dish recipes in Volume 5 will date the book faster than any other part. They're included to demonstrate the possibilities of all the techniques and ingredients we've learned about in other volumes, and to conclude the argument started in Volume 1 that all history builds to their inevitability. So classic recipes are updated and adapted, using a panoply of time-consuming steps few home cooks would attempt. Blanquette de veau, the classic veal stew, is liquefied to a warm cream called "veal nog" that requires a rotor-stator homogenizer and a centrifuge. Boeuf en gelée, the gel hot rather than cold, demands a homemade oxtail stock, xanthan gum, and low-acyl gellan.

Some cooks might try all this—perhaps ambitious professionals who haven't been able to apprentice in any of the new-wave kitchens, perhaps semi-obsessed hobbyists. But I'm not one of them, and the 30

courses at Bellevue, every one of which I tried and took notes on, didn't make me a convert. Some of the flavors and textures were revelatory: a clear, strong "beef tea" that came from a sous-vide bag; cocoa pasta, something impossible without "vital gluten" (cocoa powder has no gluten of its own), with puréed, cured sea urchin cooked sous-vide. But much of it still seems mere trickery: freeze-dried corn kernels and powders of brown butter and lime and ash in a version of the Mexican street food corn elote, the powdered fat unpleasantly greasy on the tongue; a cream of mushroom and bacon soup infused with dark miso and gelled into a too-intense foam; smoked butter made in a rotor-stator homogenizer that overwhelmed a delicate piece of fresh-caught, unfortunately brined albino salmon (cooked sous-vide, of course).

But these are matters of personal taste, and the night I visited Bellevue I was fasci-nated every moment. As I did at the Jean-Georges breakfast, I came away convinced that these techniques and ingredients will be essential for cooks of the future. It's too early to know how they'll be adapted, and which will be most frequently used, but my feeling when sampling the 30 courses was that as prices for homogenizers and centrifuges come down, thickening agents become easy to find, and even liquid nitrogen becomes commonplace in professional and then home kitchens, we'll make our own ketchup and many other staples, and come to cook dishes as basic as fried chicken and hamburgers in completely different ways.

Every big-name chef, however rooted in classic techniques, is already interested. A couple of hours after the Zagat breakfast, Vongerichten persuaded me to stay for lunch, to eat the tasting menu he was giving the chef Daniel Boulud as a birthday gift. He didn't send us 30 courses, but the number approached 20, and the flavors were a kind of musical composition that varied in volume and intensity but never in virtuosity. Almost none of them used any of the new techniques described in *Modernist Cuisine*; almost all of them strove to find innovative but nonrevolutionary ways to extract the maximum flavor and fragrance from the herbs, fish, and meat Vongerichten had in the kitchen.

But Vongerichten told me he's getting ready to be a not-quite-early adopter, even though "I tried meat glue, and I just don't understand—why do I need meat glue?" As we discussed the book after lunch—he had paged through it in the morning like a child with his first train set—he had a look in his eyes that was both wistful and determined. "I've got to make burgers that crumbly," he said. Another tank of liquid nitro sold. **tr**

CORBY KUMMER IS A SENIOR EDITOR AT THE *ATLANTIC* AND THE CURATOR OF THE ONLINE ATLANTIC LIFE CHANNEL.

CONFUSED Policies to support energy independence often conflict directly with strategies to address climate change. Coal and other fossil fuels, such as shale oil, are obvious examples.

ENERGY

Avoiding the "C" Words

Politicians and policy experts talk as if climate change can be an afterthought in energy policy. They should think again.

By KEVIN BULLIS

In his State of the Union Address this year, President Obama announced one of his administration's most significant energy-related policy proposals, one that will have a wide-reaching and long-lasting impact if it becomes law. Together with large increases in energy R&D funding, his plan calls for 80 percent of the electricity in the United States to come from "clean sources" by 2035. After the speech, the White House released documents making it clear that this proposal is aimed at cutting the emission of gases that cause global warming. Yet President Obama didn't mention carbon dioxide once in his speech. He didn't say "greenhouse gas" or "climate change." The closest he came was a passing reference to the need to "protect our planet."

Obama's rhetorical strategy—of arguing for climate-change policy without mentioning climate change—has become a common one in Washington. Since the defeat in Congress last year of cap-and-trade legislation, which would have set a specific limit on greenhouse-gas emissions, politicians who think climate change is an urgent problem have kept quiet about increasing temperatures, rising sea levels, and impending famines, even as they plan legislation to address these problems. Instead, when they talk about energy at all, they focus on developing "clean energy" to improve American competitiveness and promote energy independence.

Blueprint for a Secure Energy Future
The White House
March 30, 2011

A Business Plan for America's Energy Future
The American Energy Innovation Council
June 10, 2010

A flurry of recent energy reports from business leaders, policy experts, and think-tank analysts do sometimes mention climate change. But they often lump it together with other goals without saying which get priority, and many prescribe a one-size-fits-all solution: energy innovation. Most notably, "A Business Plan for America's Energy Future," from the American Energy Innovation Council, a group of business leaders that includes Bill Gates and GE chairman Jeffrey Immelt, calls for tripling the funding of energy R&D. The claim is that this would have benefits for the economy, national security, and even international diplomacy while addressing several environmental concerns, one of which is global warming.

The approach of talking around climate change, popular though it has become, is deeply flawed. Legislation that takes climate change seriously will look very different from legislation focused on, say, energy independence or job creation. If the legislation doesn't focus specifically on reducing greenhouse-gas emissions, the result could be much too weak to effect changes that climate scientists consider essential for averting disaster. Indeed, some policies designed to meet other worthy goals could actually increase carbon dioxide emissions. "There are a number of ways policy can go wrong if you aren't explicit about the fact that your objective is reduced greenhouse-gas emissions," says John Reilly, co-director of the Joint Program on the Science and Policy of Global Change at MIT.

Promoting energy independence by using more domestic resources can, in many scenarios, increase carbon dioxide emissions. Oil shale is just one example. It has recently been touted as a vast source of hydrocarbons in the United States, one that could supply enough petroleum for about 140 years at today's rates of consumption. But producing oil this way releases enormous amounts of greenhouse gases, as much as five times more than producing it from conventional wells.

In other cases, the trade-offs aren't as clear, and it's especially here that a lack of clearly defined policy goals can wreak havoc. Federal support for biofuels was originally intended to help corn farmers. Massive ethanol subsidies have been continued in part because of arguments that they reduce oil imports and, more recently, greenhouse-gas emissions. But researchers are finding that corn ethanol—which is often produced using fossil fuels—could actually result in more carbon dioxide emissions than gasoline.

Even advanced biofuels, which use sources such as switchgrass and require much less fossil fuel to produce, might be no better than gasoline when the impact of converting land to produce them is taken into account. Increasing our use of domestically produced biofuels can help decrease our reliance on imported oil, but it won't decrease carbon emissions unless well-considered policies provide incentives to do so. "If reducing global warming is the argument you want to make for biofuels, let's look again," says Michael O'Hare, a professor of public policy at the University of California, Berkeley.

If we are to begin reversing climate change, the reductions in greenhouse gases will have to be very large and accomplished very quickly, at least in the context of an energy industry where power plants last more than 50 years. And even strong advocates for such policies acknowledge that they will be very expensive *(see Q&A, p. 26)*. The economic justification for taking on this expense is that it will offset the far greater potential costs of global warming.

Could innovation change the economics? If solar power can be made cheaper than electricity from coal, the argument goes, the market will adopt it quickly and at a large scale, just to save money. It will be a win-win situation.

Such a vision, though, may be little more than a fantasy. Today, solar power is several times more expensive than electricity from coal plants, and it's intermittent, requiring costly storage technologies if it's to replace coal plants that run night and day. The situation is similar in transportation: batteries for electric vehicles are at least twice as expensive as they would have to be for electric vehicles to compete widely with gasoline-powered ones, and extensive recharging infrastructure is needed if people are to rely on electric cars for long-distance driving. Even if major breakthroughs can be achieved in the lab, it could take decades to commercialize them. Utilities and automakers are reluctant to adopt new technology at a large scale—it could prove unreliable or

more expensive than expected. As a result, innovations might not take hold until well after greenhouse gases have reached dangerous levels. Low-carbon power is likely to need a boost from the government if it's going to defeat fossil fuels, Reilly says: "Without a price on carbon emissions to reflect the climate implications of them, the hope that we're going to invent our way out of this and never want to go back to fossil fuels seems overly optimistic."

Stopping climate change will require huge-scale efforts that can't be justified without talking about the dangers and costs of climate change itself. In the current political environment, some experts argue, it's a good idea to hold off on serious climate legislation. "I was deeply disappointed in the failure of climate legislation in the last Congress, and that Obama did not push harder for it," says Jon Foley, director of the Institute on the Environment at the University of Minnesota. But, he says, given the global economic crisis and political turmoil in the Middle East, it is understandable that addressing climate change has not been a top priority for many Americans. "Let's get realistic here," he says. "Especially right now, I'd argue that fixing the economy and ensuring energy security are more pressing issues."

This argument may or may not make sense. The impact of greenhouse gases could be significantly smaller, or far larger, than mainstream estimates suggest. What is the right response to this uncertainty? What is the best strategy for dealing with risks that are by nature difficult to estimate? These are controversial issues, and the answers aren't obvious. Perhaps what's most insidious about the current strategy of tiptoeing around climate change is that it precludes a national discussion of these crucial questions. Effective climate policy can't be created without answering them, and to do that, politicians and policy experts need to talk about the dangers, the costs—and, yes, the opportunities. **tr**

KEVIN BULLIS IS *TECHNOLOGY REVIEW*'S ENERGY EDITOR.

hack

A KINECT

The Kinect provides data on more than 250,000 points in three-dimensional space, at a rate of 30 frames per second, with color information included. With these "eyes," the Bilibot can sense its surroundings at much higher resolution and accuracy than was previously possible without expensive equipment.

B CUSTOM POWER BOARD

Fueled by a cheap lead-acid battery, this component determines where to direct power throughout the Bilibot. It sends energy to the Kinect and the computer that processes the data it produces, and it charges the battery that the robot uses to move.

C ROBOTIC ARM

The Bilibot's robotic arm uses motors that let it lift about three pounds, which is more than many hobbyist robots can handle. Its gripper is powered by motors originally used for vent blades in air-conditioning units; Gallagher was able to buy them as surplus parts.

Seeing Robotics with New Eyes

Microsoft's Kinect provides a cheap way for robots to interact with their surroundings.

By ERICA NAONE

SINCE MICROSOFT launched its Kinect motion-detecting system for video games, hackers have been eagerly repurposing the $150 device. Garratt Gallagher, a robotics engineer at the MIT Computer Science and Artificial Intelligence Laboratory, used it to build a robot called the Bilibot that he is selling online for $1,200. The device, which is small enough for Gallagher to carry in his arms, can perceive its surroundings, move around, and manipulate objects. The Kinect is a key element, Gallagher says, because it can detect its environment just as well as a sensor that costs $5,000.

D CUSTOM COMPUTER

The robot relies on a 3.1-gigahertz Intel i3 processor with integrated graphics. In addition, it has four gigabytes of RAM and a 160-gigabyte hard drive. Gallagher tested eight different computer platforms before settling on this configuration.

E ROBOT OPERATING SYSTEM

The software that controls the Bilibot runs on top of the open-source Robot Operating System. Users have contributed packages that allow a robot to recognize gestures, track motion, and perform similar tasks. ROS is maintained primarily by a research institute called Willow Garage in Menlo Park, California.

**F iROBOT CREATE**

At the base of the robot is an iRobot Create, which is essentially iRobot's floor-cleaning robot, the Roomba, minus the vacuum. This device enables the Bilibot to move. It includes a bump sensor, four downward-facing infrared sensors, wheel-drop sensors, and a side-facing infrared sensor to find walls and way points.

www See the Bilibot in action:
technologyreview.com/hack
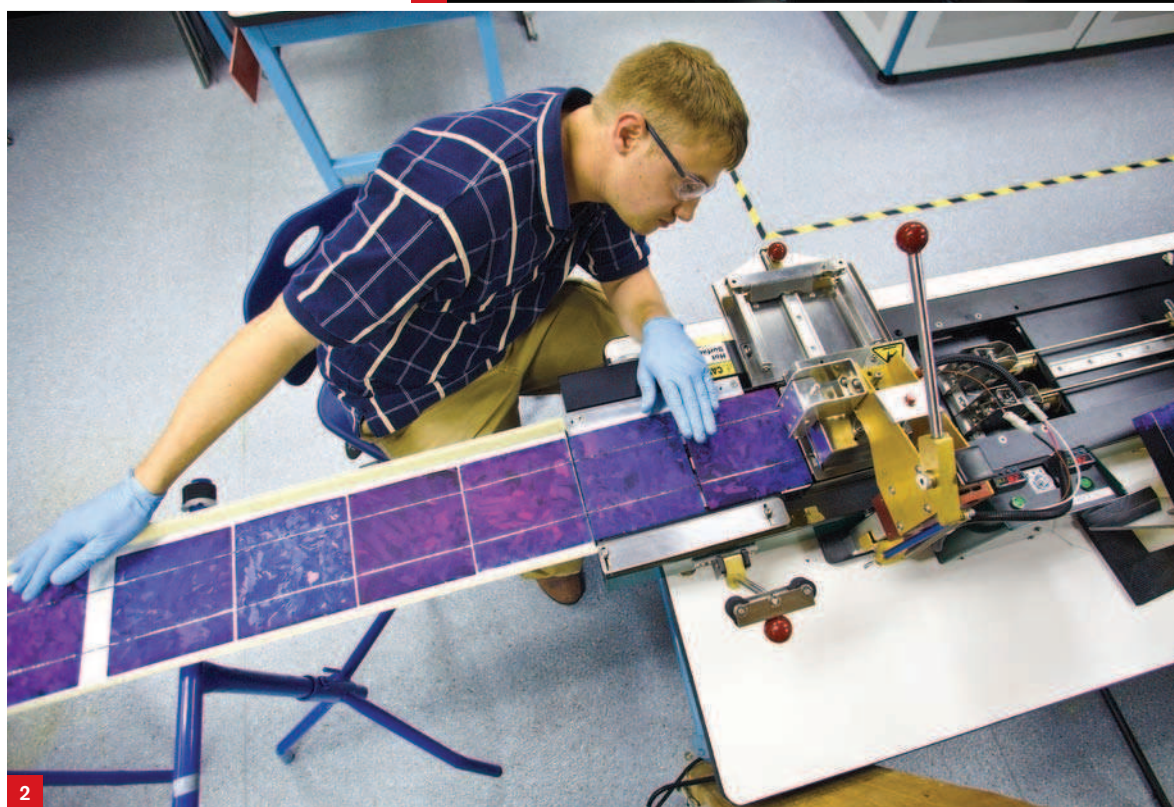
Redesigning Solar Power

A new lab is inventing innovative ways to package and install solar cells, with the aim of making solar energy far more affordable.

By KEVIN BULLIS

Many companies and researchers are trying to increase the power output of solar cells, the parts of a solar panel that absorb light and generate electricity. A lab at the Fraunhofer Center for Sustainable Energy Systems in Cambridge, Massachusetts, exists to improve everything else—the packaging that protects the cells, the junction boxes and other electronics, and the way panels are installed. Together, these factors account for about 60 percent of the cost of solar power today.

Utility-scale solar systems cost about $3.40 per watt of power they can generate (systems on the roofs of houses can cost twice that). About 26 cents goes for materials such as glass and protective coatings; that cost can be trimmed by using injection-molded frames and different materials for encapsulating the cells. Other advances could cut the cost of inverters, which now amount to 22 cents per watt, and the mounting hardware (about 25 cents). Then there's wiring, labor, and design costs. The list goes on.

"They may seem like incremental improvements, but all of them together have an enormous potential to reduce costs," says Christian Hoepfner, director of technical operations at the center, which will work with the solar industry to commercialize these improvements. One main task is to make sure that the changes don't reduce the panels' durability. Neither increasing power output nor decreasing installation costs would do any good "if the panels don't last for 25 years," he says.
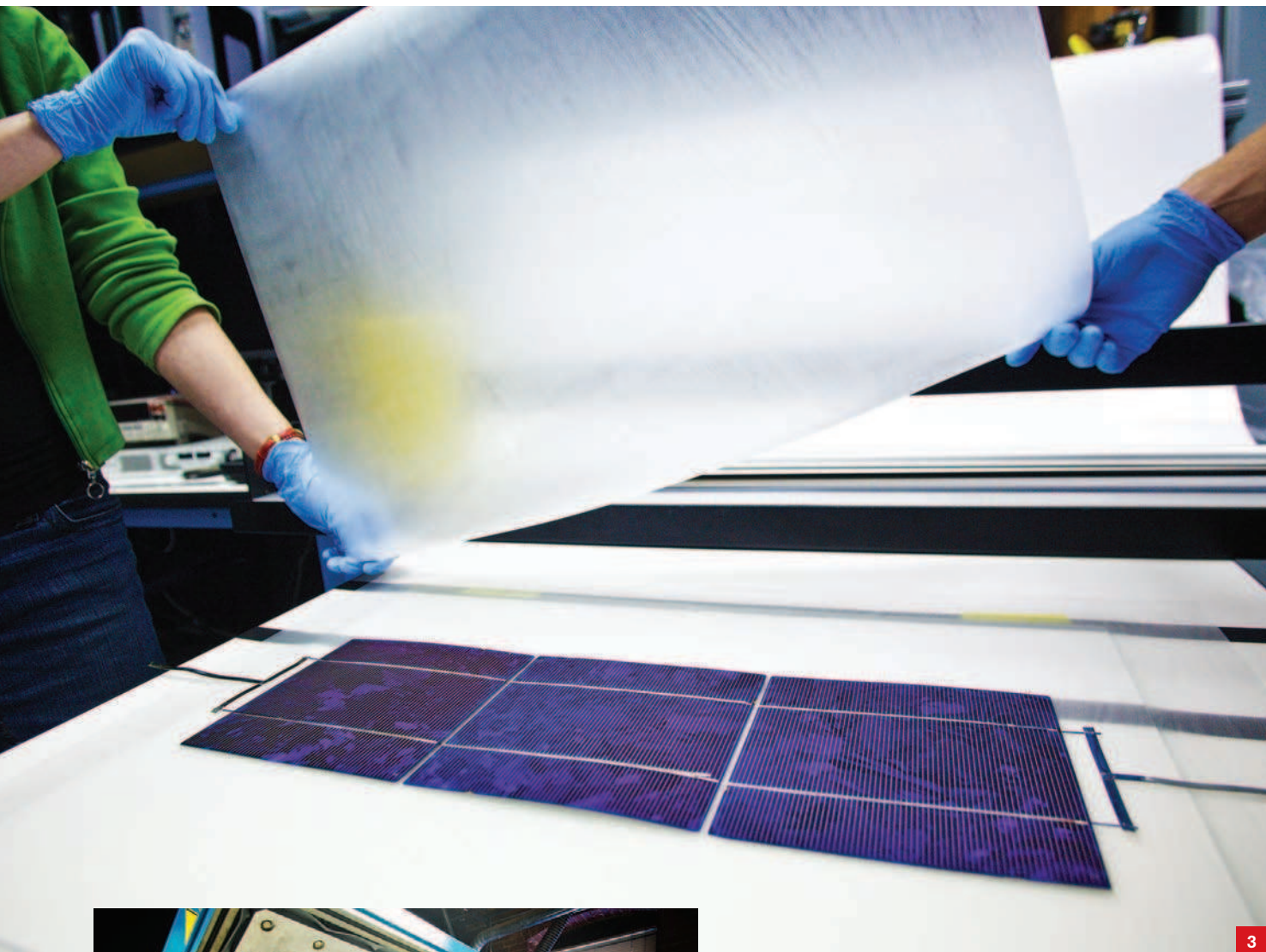
3

4

1. Fraunhofer scientist Theresa Christian tests the power output of a solar cell, the basic device within a solar panel that absorbs light and converts it into electricity. The lab doesn't design solar cells, but building solar panels requires knowing how well they perform, because a panel's power output is limited by its worst-performing cell.

2. Once the cells are sorted by power output, another researcher, Adam Stokes, strings them together with a tool that solders flat strips of metal called busbars to electrical contacts on their front and back. The lab can test different ways to connect the cells, varying factors such as the number and type of busbars and then measuring the resulting performance to determine whether any extra costs are worthwhile.

3. Researchers sandwich a short string of solar cells between glass and a protective film, a process designed to keep the cells dry. This panel will be small enough to fit in one of the specialized chambers the lab uses to test new materials being considered for adoption by the solar industry.

4. A large laminating machine operated by Dan Doble, group leader for the PV Modules Group at Fraunhofer, seals solar cells inside a protective package. To earn back their cost, solar panels must perform well for decades, often under extreme conditions. If even a small amount of water vapor enters the panel, it can corrode contacts and degrade its performance.

5. This chamber can subject solar panels to a wide range of temperatures and humidity levels. It includes a device invented at the Fraunhofer lab that presses on the surface of a panel by inflating a rubber bladder, simulating pressure from a load of snow. Solar power may be associated with warm, sunny climates, but some of the biggest markets are in snowy places such as Germany.

6. Researchers Dan Doble and Carola Völker lower a solar panel into a tank of water to test how well the circuitry within it is sealed. A current of at least 500 volts is applied to the circuits, and an electrical lead in the water detects any current leakage. The test can help determine whether the panels are likely to survive exposure to extreme temperatures and mechanical pressure. The researchers also study micrographs to detect damage.

7. In most solar panels, a hole is cut in a protective envelope surrounding the solar cells to allow a connection to an outside circuit. To speed manufacturing and avoid allowing water to leak in, the lab is developing a device (right) that can be installed before the cells are encapsulated. The yellow tabs can be inserted between a sheet of encapsulant and the cells and sealed in place during a standard lamination step. The cables sticking out of the device are connected to similar cables in neighboring solar panels on a roof before the panels are connected to an inverter and the power grid. In the current design, this is done by hand, but in a future design, the devices will snap together, allowing the panels to be installed quickly and cheaply.
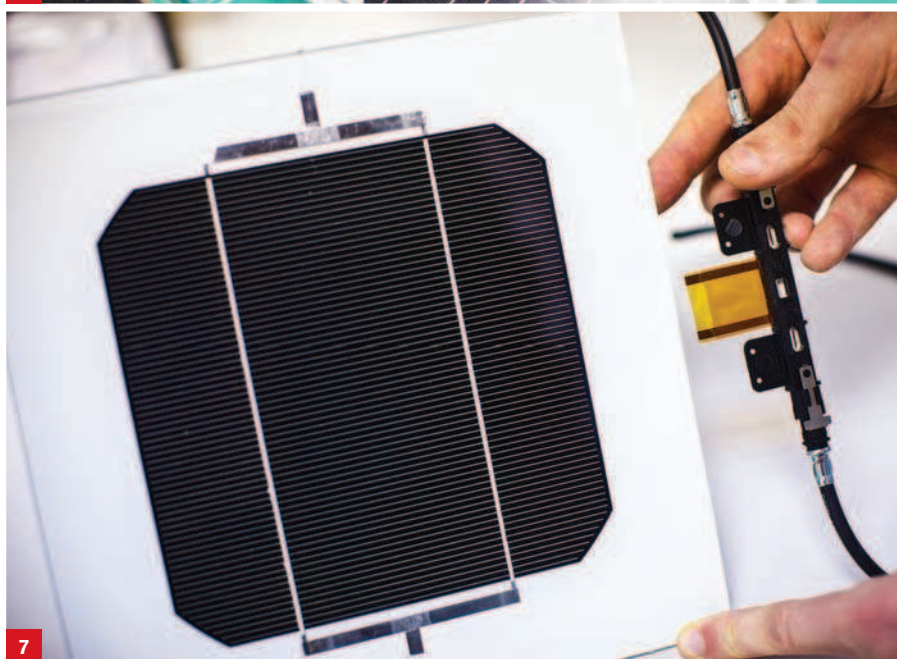
www See a video of solar panels being made and tested: technologyreview.com/demo

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Germ-Stabbing Particles

New type of drug kills antibiotic-resistant bacteria

RESULTS: Nanoparticles designed to disrupt the cell membranes of a large group of pathogens, including multidrug-resistant *Staphylococcus aureus*, cause the cells to burst open but don't harm human red blood cells.

WHY IT MATTERS: Because the nanoparticles don't target a specific genetic pathway, researchers hope bacteria will be slow to develop resistance to them. Previous attempts to make polymers that kill microbes by poking holes in cell membranes have raised safety concerns because they tend to harm some animal cells, too, or they haven't worked as well in the body as they did in a test tube.

METHODS: Chemists at IBM Almaden Research drew on a library of previously developed polymer building blocks to make nanoparticles that would target the cell membranes of a large group of infectious agents called gram-positive bacteria. The polymers are designed to self-assemble in water or blood, forming spherical nanoparticles whose outer layer interacts with these cell membranes. They're also tailored to be broken down by the body after a short time. In test tubes, the nanoparticles killed several kinds of bacteria—including drug-resistant staph, a major issue in hospitals—and some infectious fungi as well. The researchers also demonstrated that the nanoparticles didn't harm human red blood cells in test tubes and had no apparent ill effects on mice that were injected with them.

NEXT STEPS: Further tests are needed to prove that the polymers are safe. And the researchers will have to show that the drugs work in the complex environment of the human body.
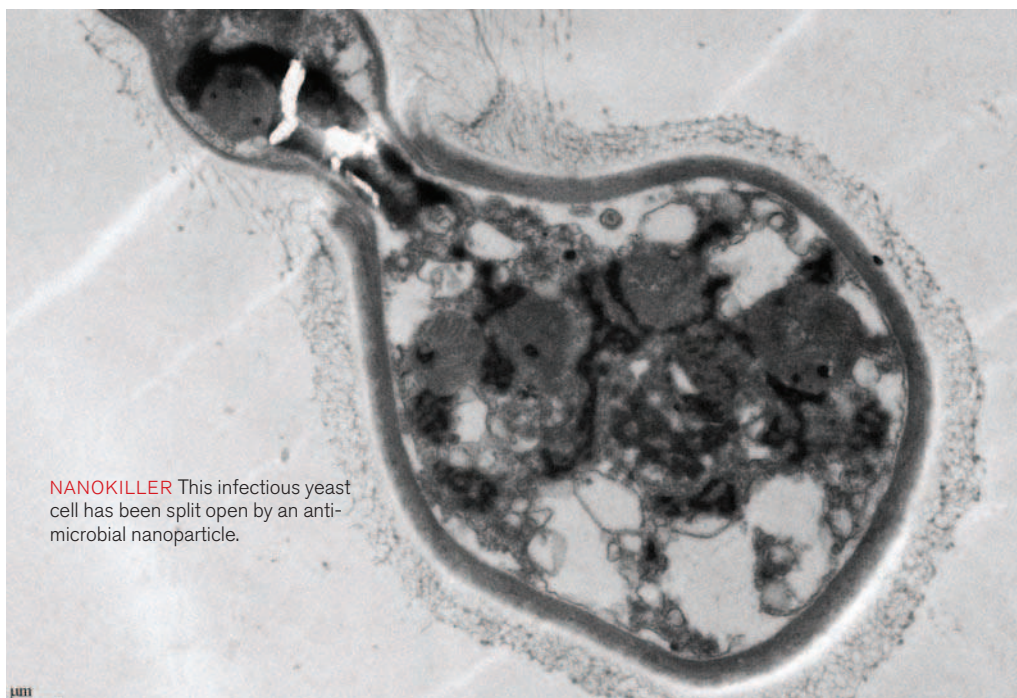
NANOKILLER This infectious yeast cell has been split open by an antimicrobial nanoparticle.

Quick-Charging Batteries

A new type of cathode could enable cell phones to recharge in just 30 seconds

RESULTS: A new way of making battery electrodes from metal foams has yielded a lithium-ion battery that recharges 50 times as fast as traditional ones, without compromising the total amount of energy stored. The prototype can recharge to 90 percent of its capacity in two minutes.

WHY IT MATTERS: The main limit on recharging speeds today is the movement of electrons and ions in and out of one of the battery's two electrodes, the cathode. The new cathode has a highly porous structure that allows ions to move in and out speedily. The metal substrate itself is highly conductive, and the structure has a large surface area, so it can be coated with enough active battery material to store a large amount of energy. The design is compatible with a range of different battery types. Cell phones incorporating this technology could recharge in 30 seconds, and electric cars could recharge in the time it takes to fill a gas tank.

NATURE CHEMISTRY

METHODS: Researchers at the University of Illinois at Urbana-Champaign first made the metal foam for the electrodes, starting with a matrix of tiny polymer spheres. They used a common method called electroplating to coat the spheres with nickel, then dissolved the polymer and polished the metal, leaving a spongelike nickel foam that's 90 percent open space. Finally, they grew active battery materials on the foam and combined the finished cathode with an anode and an electrolyte to create complete cells.

NEXT STEPS: The Illinois group will have to prove that the cathodes can be manufactured economically. They're also working on demonstrating the cathodes with a wide range of batteries to see whether recharging times can get even faster.

BIOMEDICINE

Evolving Faster

A new way of directing protein evolution could speed drug development

RESULTS: Scientists used a new approach to create an enzyme designed to bind to a specific target. The process, which involved 200 rounds of protein evolution that would have taken years with conventional methods, was completed in just a week.

WHY IT MATTERS: Directed evolution—sequentially introducing mutations into a protein to generate a molecule that performs a desired function—can create antibodies and other proteins that fight diseases, including cancer. But current methods are often too slow and labor-intensive to be broadly useful in drug development.

METHODS: Researchers engineered M13, a rapidly replicating bacteriophage that infects *E. coli*, to carry a gene for the protein they wanted to modify. They then grew the viruses inside *E. coli* cells in an environment designed to boost the number of mistakes made when the viral DNA was copied, generating a library of slightly different proteins. The researchers linked the desired function, such as the ability to bind to the target, to a substance the viruses needed for survival, so only those viruses with the best versions of the protein progressed to subsequent rounds of evolution. Evolution took place at a rate of up to 40 rounds per day, 100 times the rate achieved with other methods.

NEXT STEPS: The team plans to use the system to produce therapeutic proteins and to study seminal questions in evolution, such as whether replicating the same evolutionary conditions will generate different outcomes—and what factors determine these outcomes if so.

Growing Retinas

Embryonic stem cells growing in a dish spontaneously form retina-like structures
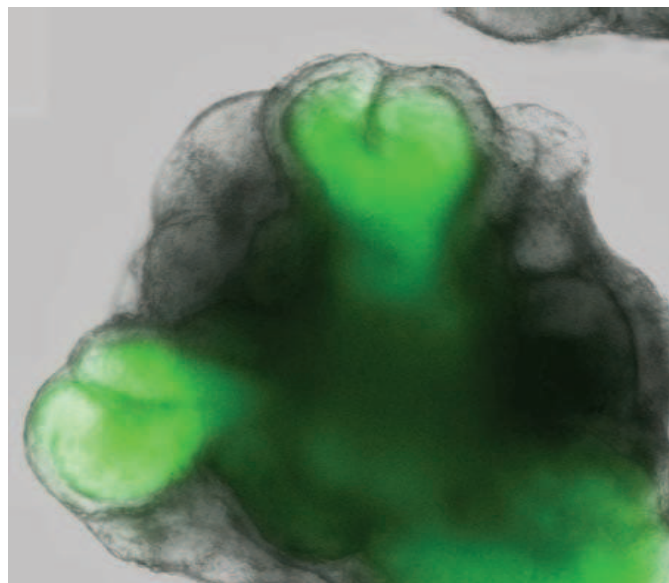
RESULTS: Mouse embryonic stem cells growing in a dish can spontaneously assemble

THE EYES HAVE IT A soup of chemicals and undifferentiated embryonic stem cells (gray) growing in a dish spontaneously generates two cup-shaped structures (green), which resemble the embryonic retina.

into three-dimensional structures reminiscent of the early embryonic retina.

WHY IT MATTERS: Most efforts to grow organlike structures from stem cells involve some kind of scaffolding, often coated with specific signaling molecules, to encourage growth of the proper cell types and tissue architecture. But these findings show that at least some aspects of organ development are preprogrammed into the cells, suggesting that it may be possible to grow some tissue structures much more simply. Such retinal tissue might eventually be able to replace human tissue damaged by degenerative eye diseases.

METHODS: Researchers began with about 3,000 mouse embryonic stem cells mixed with a cocktail of chemicals involved in retinal development. Over a two-week period, clusters of stem cells began to grow into balloonlike sacs, which then grew inward. These dual-layer structures resembled the optic cup, an early developmental precursor to the retina.

NEXT STEPS: The group is now working on transplant-

ing these structures into blind mice, in the hope of restoring vision. They are also trying to replicate the research using human cells and hope to have a human version of the system within two years.

INFORMATION TECHNOLOGY

A Processor for Apps

Custom design could extend smart-phone battery life

SOURCE: "GREENDROID: EXPLORING THE NEXT EVOLUTION IN SMART-PHONE APPLICATION PROCESSORS"
Steven Swanson and Michael Bedford Taylor
IEEE Communications (4): 112–119

RESULTS: Researchers at the University of California, San Diego, proposed a chip design that is specialized for Android mobile devices. They showed that the chip could be 11 times as energy efficient as a conventional mobile processor in running Google's Android mobile operating system and popular apps.

WHY IT MATTERS: The capabilities of smart phones and other mobile computing devices are limited by the capacity of their batteries. For decades, computer processors have steadily gotten faster while their power consumption has stayed the same, but transistors are now so small that they cannot be operated faster or packed more densely onto a chip without an increase in power use. New ways to make mobile chips

more efficient must be found if mobile devices are to continue gaining computing ability and taking on new functions.

METHODS: To make the chips, software was used to record the computational tasks a phone faced when running popular apps for e-mail, maps, video, and the Web radio service Pandora, among others. A tool developed by the researchers then translated the most commonly used code from those apps into specialized physical circuits to be added to the chip design. Those circuits closely mimic the information processing specified by the app code, enabling the chip to perform its most common tasks much more efficiently than a general-purpose computer processor.

NEXT STEPS: The researchers have partnered with chip manufacturer Global Foundries to produce a physical proof-of-concept prototype, which is expected to be ready by late summer. The prototype chip will use transistors smaller than those currently on the market, with feature sizes as small as 28 nanometers. (The most advanced chips available today have 32-nanometer features.) It will be installed in a prototype mobile device running a real operating system and apps so that its energy efficiency can be compared with that of conventional chips. A second prototype chip designed to handle a wider range of Android applications is expected to be ready by the middle of next year.

Measuring Gestures
How to turn the body into a functional antenna

SOURCE: "YOUR NOISE IS MY COMMAND: SENSING GESTURES USING THE BODY AS AN ANTENNA"
Gabe Cohn et al.
Proceedings of the CHI Conference on Human Factors in Computing Systems, Vancouver, British Columbia, May 7–12, 2011

RESULTS: Researchers at Microsoft and the University of Washington demonstrated that the human body can be used as an antenna to direct electromagnetic "noise," or ambient radiation—in this case from wiring in a wall. The resulting signal could be used to control a gesture-based interface.

WHY IT MATTERS: Gesture-based interfaces such as the Nintendo Wii and the Microsoft Kinect have transformed gaming. The new work, which represents a novel way to measure gestures, could make such interfaces less expensive and easier to install. The system could use electromagnetic radiation from home appliances and mobile-phone signals as well as from home wiring.

METHODS: The system is designed to pick up signals produced by interactions between the human body and objects that give off electromagnetic radiation. To capture those signals, the researchers had test subjects wear a grounding strap, a bracelet normally used to keep static electricity from building up

in the body. In this case, the grounding strap detected the change in electromagnetic radiation in the body. The energy was directed to a connected analog-to-digital converter, to change the signal into a form that could be fed to a laptop; the laptop ran it through algorithms designed to determine the person's location within a house and orientation with respect to the wall. To control a gestural inter-

HUMAN ANTENNA A person's body can direct stray electromagnetic radiation in the environment.

face, the system will first have to be trained to recognize the normal landscape of electromagnetic radiation and detect any changes. Systems like the Kinect require a similar type of spatial training.

NEXT STEPS: The researchers want to make the system smaller and more portable. For example, instead of using a laptop to collect and process the gestural data, they'd like to be able to use a phone or watch. They'd also like to be able to analyze the data in real time. **tr**

MICROSOFT RESEARCH

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Delayed Reaction

Warnings about climate change were coming half a century ago.

By TIMOTHY MAHER

EARLY WARNING Columbus Iselin, former director of the Woods Hole Oceanographic Institution (seen in background), examined how global warming could change ocean currents, which in turn could accelerate the warming trend.

Concerns about global warming and how to address it (*see Q&A, p. 26*) have a long history. The First World Climate Conference was held in 1979, and the United Nations created the Intergovernmental Panel on Climate Change in 1988.

Yet even those steps came well after scientists had begun taking the issue seriously. One example can be found in the November 1960 issue of this magazine, in which science journalist Robert C. Cowen warned that "we are performing a carbon-dioxide experiment which may change our climate."

To be precise, the carbon-dioxide experiment began with the industrial revolution, when men started burning fuels in unprecedented amounts. Since the beginning of that revolution they have produced something like 12 per cent of the total carbon dioxide already present in the air. The capacity of the oceans to absorb this gas is enormous, however. Most of the excess produced in the past century probably has been removed in this way. The next century will be different.

Cowen cited Columbus Iselin, an MIT professor and former director of the Woods Hole Oceanographic Institution, who theorized that higher temperatures resulting from increasing carbon dioxide emissions would eventually prevent polar regions from producing enough cold, dense water to drive the "thermodynamic flywheel" that sends tropical waters into northern latitudes. Stifling the flywheel, Iselin said, would limit the amount of carbon dioxide absorbed by the oceans, with unpredictable results.

If the ocean's ability to soak up carbon dioxide is reduced, this would increase the greenhouse warming effect as more of that gas accumulated in the atmosphere. Thus there may be a climatic persistence effect due to the oceans which enhances warming after such a trend has started. Once the climate has warmed up to a certain point, the oceans would stop overturning. Because less carbon dioxide would be removed from the atmosphere, this in turn would accentuate the warming trend, which would tend to persist.

Cowen stressed the uncertainty of long-term climate predictions, a problem that still dogs scientists. He noted that most scientists believed just a slight drop in global temperatures could spur an ice age. British geophysicist George Simpson, meanwhile, speculated that slightly *higher* temperatures could bring on a new ice age by increasing the amount of moisture in the atmosphere, which could mean heavier snows and growing glaciers.

Given that Earth's climate was so delicate, so variable, and constantly in flux, predictions were hard enough, wrote Cowen. Now humans, with their "carbon-dioxide-producing industry," had thrown yet another factor into the mix. Maybe experts couldn't predict the consequences, but they felt safe in saying the results could alter the world.

The influence of this new and geologically unique factor may be operating in any of several directions. It could be tending toward a new ice age or could just as likely be producing another great tropical epoch like that prevailing when coal and oil deposits were laid down. Perhaps its influence is more moderate than such extremes suggest. The interactions are so involved that experts do not yet know how to sort them out. One thing they are sure of—this influence is at work on a scale to dwarf all previous changes man has made.

Cowen, now 84 and living in Concord, Massachusetts, retired this year after 45 years as a staffer and 15 as a columnist for the *Christian Science Monitor* (he's also a former member of *TR*'s editorial advisory board). He notes that the theory of global warming actually dates back to the 19th century and was gaining ground "around the fringes" of the scientific community by 1957. He first wrote about it for the *Monitor* in 1958, in an article that he suspects might be the first on the subject by any American reporter.

He says scientists are partly to blame for our slow response, because they've done a poor job of explaining why the average person should care about melting ice caps. They could have focused more on the effect that drought would have on food prices, for instance. But he says that even the most ardent deniers will come around in time: "Eventually they'll be able to look out their windows and see the results themselves." **TR**

TIMOTHY MAHER IS *TR*'S ASSISTANT MANAGING EDITOR.

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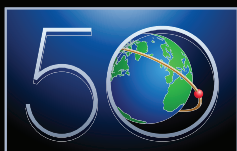
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